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THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES EQUIPMENT AND SUPPLIES ASSOCIATION.

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Foundry Technical Institute, Meek's Road, Falkirk *(Telephone 332).*

The Nursery.

In his Presidential Address to the Institute of British Foundrymen, yesterday, Mr. Andrew Harley touched upon a phase of modern industrial activity which is seriously reacting upon the foundry. He aptly termed this "passing the baby," but failed to point out that "it" (as representing the reduction of manufacturing costs) was merely being returned to its rightful home—the nursery. If a casting is produced economically, is sound, strong and easily-machinable, the receiving factory or department is well on the road to out-distance its competitors.

Mentally, we discriminate between "passing the baby" and the American expression "passing the buck." The former, to our mind, is a modern adaptation of *rerum cognoscere causas*, or to probe matters to their true beginnings, whilst the latter is related to the evasion of responsibility.

The "nursery" is now recognised as being of paramount importance for the future welfare of the nation, and so, too, the foundry occupies a parallel position in the industrial development of a country.

Nurseries, whether cricket or horticultural, are usually controlled by specialists, are places for research and experiment, and are universally recognised as such. Foundries must perforce fulfil similar duties for industry, and be accorded adequate recognition for successes. This was never done by the old-fashioned mechanical engineer, but within the last few years the newer branches of engineering—automobile, aviation and motor-boat designers—have consistently lauded the important part played by the foundry staff. In stressing this question we are merely translating into words the spirit dominating the Conference now in session. The founders realise that they have achieved full recognition of their science and art by the newer branches of engineering, and they demand as their right similar treatment from the older sections, such as railway, marine, textile and the rest, knowing that they can, through co-operation, produce lighter and better machinery at a reduced cost. This co-operation must not be mere lip service, but real help by the provision of modern machinery and skilled metallurgical assistance; in fact, just the type of assistance found in the modern nursery.

The Inferiority Complex.

Perhaps some remarks made by Prof. D. Hanson in his recent lecture, reported in our last issue, to the London Branch of the I.B.F. will help to dissipate what we can only describe as the inferiority complex shown by many founders towards wrought materials. This is not the only piece of evidence which has been brought to light in the past year or so reflecting much more favourable light on cast iron than is commonly expected even on the part of its most enthusiastic adherents. It was pointed out that at high temperatures—and the address referred to concerned cast alloys for high-temperature service, a very common requirement in these days—wrought materials, the elasticity of which is so highly prized, lose that elasticity to a large extent. They no longer are able to resist high stresses without deformation. High-temperature service demands stiffness and not plasticity or semi-plasticity at the working temperature, and hence a metal may be very good at the working temperature and rather brittle at ordinary air temperature; conversely, it may be plastic at working temperature and strong at air temperature.

It was also pointed out that the crystalline structure of a cast metal is stable, and not easily modified under heat, whereas rolled and wrought materials are subject to the coalescence of grains called grain growth. Much work has been done in recent years on what has become known as creep, as the U.S.A. Exchange Paper read yesterday at the Birmingham Convention demonstrates. A ductile material will extend in length under a comparatively small load if that load is applied for a long time and the material be heated. So general is this experience that engineers to-day do not expect to get a non-creep material; they set a limit above which the creep must not go. Prof. Hanson also mentioned that under creep conditions cast metals often behave better than wrought materials. These facts go a long way to explain the universality of cast iron, and founders appear to have everything to gain rather than to lose by the development of tests under actual service conditions, as compared with ordinary static tests on test-bars.

It is well known that cast iron suffers very little if any diminution in tensile strength up to 400 or 450 deg. C., and with suitable alloy additions this may be made still higher, and it is reasonable to conclude that the other mechanical properties follow on similar lines.

XUM

Mr. L. H. Pomeroy.

Managing Director of the Daimler Company, Limited.

MR. LAURENCE H. POMEROY, managing director of the Daimler Company, Limited, who is presenting a Paper at the Birmingham Convention to-day, was born in London in 1884. He served a regular apprenticeship as a mechanic to the large locomotive building works of the North London Railway Company, during which time, at the early age of 19, he gained a Whitworth Exhibition, being placed sixteenth in open competition.

He then commenced his career in the offices of Messrs. Humphrey & Glasgow, water-gas engineers, subsequently proceeding to Messrs. John I. Thornycroft, the famous marine engineers. In 1905 he became a draughtsman at the Vauxhall and West Hydraulic Engineering Company, of Lambeth, who since 1903 had been making Vauxhall motor cars. In 1907, however, this firm was succeeded by Vauxhall Motors, Limited, and Mr. Pomeroy was then

MR. L. H. POMEROY, M.I.Mech.E., M.I.A.E.,

(*Managing Director, Daimler Company, Limited.*)

transferred to the new works at Luton, Bedfordshire. Here he was successively appointed works manager, chief engineer and technical director, becoming responsible not only for the design of all Vauxhall products, but also for the entire administration of the Vauxhall Works. Under his direction Vauxhall cars early achieved remarkable success in racing and reliability trials; and after the intermission of valuable war work he designed the famous 30/98 Vauxhall, probably the fastest standard touring car of its size ever produced.

In 1919 Mr. Pomeroy severed his connection with Vauxhall and proceeded to the United States, where he resided for nearly eight years. His principal activities were concerned with the Aluminium Corporation of America, and the Pierce Arrow Motor Car Company. During this stage of his career Mr. Pomeroy was responsible for much pioneer work in the scientific application of light alloys to motor-car construction—work that has since borne valuable fruit both in America and in this country.

In 1926 Mr. Pomeroy, at the invitation of Mr. Percy Martin (managing director of the B.S.A.-Daimler group of companies), returned to England to take up the position of chief engineer to the Associated Daimler Company—an amalgamation of the commercial vehicle interests of the Daimler Company with the Associated Equipment Company. Two years later, however, the Daimler Company resumed their own activities in the field of passenger commercial vehicle construction at Coventry, and Mr. Pomeroy was then appointed general manager of the Daimler Company. Within a year he became managing director, which position he still holds.

While with Associated Daimler, Mr. Pomeroy began experimental work in connection with the application of a novel form of hydraulic transmission to the motor vehicle. There were many obstacles to be overcome, but with characteristic persistence Mr. Pomeroy gradually eliminated them, with the result that last year he was able to offer to the motoring public as a proved proposition the epoch-making invention now well-known as the Daimler fluid flywheel.

Mr. Pomeroy's intensive study of light alloys has also proved of great value in his design of current Daimler cars and motor-omnibus chassis, which are consequently notable for their high power-weight ratio, swiftness of acceleration and economy of upkeep. Since coming to Coventry he has also carried out a complete re-organisation of the Daimler factory, which is now equipped with the very latest and approved production machinery.

Mr. Pomeroy is a member of the Institution of Mechanical Engineers, a Vice-President of the Institution of Automobile Engineers, a member of the Society of Automotive Engineers (America), and a Whitworth Exhibitioner.

Birmingham Convention Fund.

Mr. F. K. Neath, the hon. convention secretary, has sent us a final list of subscriptions to the Birmingham Convention Fund. This list is printed below.

	£	s.	d.
Amount previously acknowledged ...	312	7	0
J. W. Jackman & Company, Limited	5	5	0
Guest, Keen & Nettlefolds, Limited	5	5	0
Coventry Metallurgical Company, Limited	5	5	0
Matterson, Huxley & Watson, Limited	5	5	0
Albion Drop Forgings Company, Limited	5	5	0
Humber, Limited	5	5	0
Sheepbridge Coal & Iron Company, Limited	5	0	0
Alvis Car & Engineering Company, Limited	3	3	0
Fozel Castings Company, Limited...	3	3	0
Triumph Cycle Company, Limited...	3	3	0
White & Poppe, Limited	3	3	0
Phœnix Castings, Limited	3	3	0
Strakers & Love, Limited	2	2	0
Holbrooks Foundry, Limited... ...	2	2	0
Pneulec, Limited	2	2	0
Reliance (Coventry), Limited ...	2	2	0
North Eastern Iron Refining Company, Limited	2	2	0
Mr. Alex. Craig...	2	2	0
Dickin Bros., Limited	2	2	0
Mr. J. Fallon	1	1	0
Mr. H. Toplis	1	1	0
Martha Simm & Sons, Limited ...	1	1	0
Globe Foundry (Coventry), Limited...	1	1	0
Mr. E. M. Boote	1	1	0
E. Pugh & Company	1	0	0
Mr. D. Dalrymple	1	0	0
Mr. H. Field	0	10	6
Mr. W. H. Moore	0	10	6
Total	387	12	0

Random Shots.

Congratulations this week go to Jimmie Duncan, the patternshop storeman of Mavor & Coulson, Limited, and his twenty-one associates, who hazarded nimble sixpences in an Irish Sweepstake ticket, drew Orpen, and are now the richer by £15,000. Three foundry labourers, fifteen moulders and two machine men participate in this windfall.

* * *

A NEW LA FONDERIE FABLE.

There were once twenty-five young founders who went to stay at a seaside resort in the South of England. Each knew the other twenty-four by sight, but did not deign to recognise or associate himself with them. You see, each was a quite superior type of person. One afternoon one of them decided to hire a rowing-boat, and as he went to do so, passed a man, wearing captain's uniform and a wig, who had been looking out towards the harbour Bar. "Not going for a row, are you?" asked the captain. "Yes," replied the young founder, shortly. "Wouldn't advise you to," the captain said. "The sea's not smooth enough for cockleshells. Come for a trip in the 'Bia.' Stout little craft she is."

He pointed to the "Bia," a strongly-built vessel, crowded with jolly fellows who were singing "The more we are together." At that moment a Scotsman from the bow blaired across the water, "Only twenty-five more for the 'Bia.' The chance of a lifetime!"

* * *

The young fellow refused to avail himself of this chance. And so, too, did the other twenty-four, when they also came to hire boats. The "Bia's" captain warned each one in turn against bad weather, but they paid no heed. Yet by the time they had rowed out to sea they found themselves to be all at sea. They wished they had been less superior and less self-confident. A strong wind blew from the Continent, and, as it increased in force, it dumped more and more water into the cockleshells. The twenty-five frantic oarsmen realised that instead of being founders they were being foundered. And being founded, too, for they were cast into the sea; and boats and fine young fellows sank down and down and down into Carey Street's Locker.

Moral.—Join your representative Employers' Federation.

* * *

IMAGINARY INTIMATE INTERVIEWS.

VI.—*The Company Chairman.*

Depression. Ah, yes, depression. Yes, I've heard of depression. Yes. Mental *and* trade. But they need not go hand in hand. No. Decidedly no. My income is depressed. I am not. But my managing director is depressed. Profoundly. Bad. You are not depressed, are you? That's the stout and proper spirit! No depression! Depression is a figment of disordered journalism. Yes, no doubts about that. Gloomy profession, journalism. But you're not gloomy. No, you're smiling, you are. Yes. Er —— depression. Wrong way we look at it. Ought to revel in it. Whole-heartedly. Searching practical test of industry's efficiency. Free of charge, too. Splendid opportunities of tightening up efficiency. Eliminating waste. Business health tonic. Yes. Survival of the fittest. Bowls over the inefficient. Almost bowled over my company. My managing director says so. Ask him. Dreary pessimist, my managing director. Morbid. Melancholy. Tries to depress me. Bag of no-dividend gas. Dismal dismissals. Bad. Wants stopping. Act of Parliament. Here he comes. Wrinkles. Sagging chin. Inflicts penance on me. Will now. But I won't be depressed. No. Firmly refuse. Yes.

MARKSMAN.

Silicon as an Alloying Element.*

By J. Arnott, A.I.C.

[*This Paper reviews the following alloys:—iron-silicon; copper silicon; silicon-bronze; aluminium-silicon; nickel-silicon; and nickel-copper-silicon. Special stress is placed upon the usefulness of silicon bronze.*]

Introduction.

The elements iron, copper, aluminium and nickel form the basis of practically the whole output of the foundry industry. These metals in the pure state have very limited applications as castings, and are therefore alloyed with other elements in order to improve strength, hardness, resistance to corrosion, and casting properties, *e.g.*, copper is alloyed with tin and zinc, aluminium with copper and zinc.

In recent years the element silicon has become available in a state of purity and at a price which merit consideration of its possible utility as an alloying element, and it is interesting and profitable to consider its influence on the four basis metals mentioned. Silicon has much to commend it from this point of view. Its oxide, SiO_2, is widely distributed and practically unlimited in quantity, hence the price of silicon is not likely to be subject to wide price variations as in the case of tin. Silicon is now produced in many countries where cheap electrical power is obtainable.

Silicon is a light metalloid, with a specific gravity of about 2.3, and although in the percentages used in its alloys this does not make much difference in gravity, yet it is in the right direction. Its melting point (1,400 deg. C.) brings it within the capacity of ordinary pot-fire melting, and it forms many rich alloys of suitably low melting point. Further, neither the metal nor its oxide are readily attacked by ordinary corrosive agents, hence it might be expected to confer some degree, at any rate, of corrosion resistance on alloys made from it. Silicon alloys as a whole have good properties from the foundry point of view. Silicon confers fluidity and does not give rise to the formation of troublesome oxide films such as are found in, say, copper alloys containing aluminium.

Influence on Common Elements.

Proceeding, then, to review briefly the effect of silicon on the basis metals, there are:—

(1) *Iron-Silicon Alloys.*—Here a silicon content of 14 per cent. gives an alloy of high resistance to even strong mineral acids such as sulphuric and nitric acids. This silicon-iron is brittle and almost unmachinable, but in spite of its poor physical properties it finds extensive use in chemical manufacture. At lower silicon contents another useful series of alloys is found. The British Cast Iron Research Association has recently developed a series of growth-resisting, scale-resisting alloys at 5 per cent and above of silicon, with or without the addition of other elements such as aluminium, chromium, etc.

(2) *Copper-Silicon Alloys.*—Until quite recently this series appears to have received little attention, and references in technical literature are very few. These alloys were explored at Cathcart some years ago in the course of an investigation with the object of finding a substitute for gun-metal with its 10 per cent. of tin, which at that time was at a high price and spoken of as likely to go still higher. Silicon was tried as a substitute for tin, and it was found that, when alloyed with copper, 4 per cent. silicon was fully equivalent to 10 per cent. tin in hardening effect. Using silicon as a hardener, several series were investigated containing nickel, manganese and zinc respectively, as additional constituents.

Finally it was found that an alloy of approximately 94 per cent. copper, 4 per cent. silicon, 2 per cent. zinc had suitable physical properties and hardness, and it was resolved to introduce it into the foundry to test its suitability as a casting alloy. It did not take much time to recognise the characteristics of the alloy and its suitability for certain designs of castings. In the first complete year (1928) 40 tons of finished castings were made. The silicon is introduced by means of a hardener containing 40 per cent. silicon and the balance copper. In making this, the copper is deoxidised with phosphorus before adding the silicon. In making up the final alloy, care must be taken to stir the melt thoroughly. The hardener tends to float and give a heterogeneous cast. If this happens, some of the castings will be too rich in copper and soft, while others, too rich in silicon, will be brittle. The hardening effect of silicon is so powerful that at somewhere round 6 per cent. brittleness sets in.

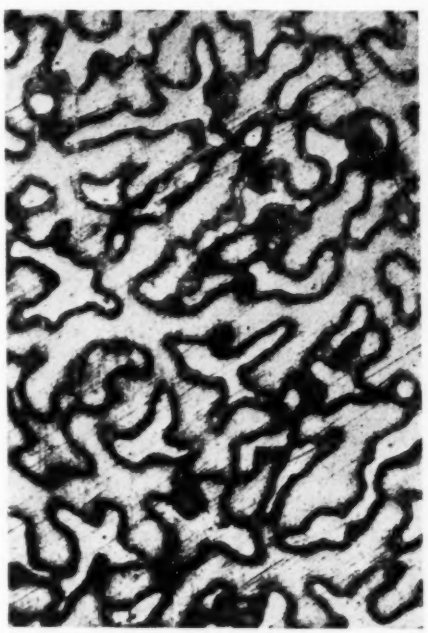

FIG. 1.—STRUCTURE OF CAST SILICON BRONZE. ETCHED WITH FERRIC CHLORIDE. × 100 DIAS.

It is unnecessary to use the highest quality of silicon because small quantities of iron, the chief impurity in lower grades of silicon, do not appear to impair the properties of the alloy. The zinc is incorporated simply to aid casting. In any applications where the maximum resistance to acid is required, zinc may be omitted and a little extra phosphorus added. The casting temperature does not require any more careful attention than that of ordinary gun-metal.

Table I details the main features of this alloy, which will be referred to as S.B. (which may stand for silicon bronze).

TABLE I.—*Characteristics of Silicon Bronze.*

Melting point	About 950 deg. C.
Specific gravity	8.4
Tensile strength	16 to 22 tons per sq. in.
Elastic limit	5 tons per sq. in.
Yield point	7 to 10 tons per sq. in.
Elongation..	10 to 25 per cent.
Modulus of elasticity ..	6,800 tons per sq. in.
Coefficient of expansion between 15 and 400 deg. C.	18.0 × 60^6 per deg. C.

Characteristics of S.B.

High Temperature Strength.—The strength at high temperature is slightly higher than that of Admiralty gun-metal but not sufficiently so to make it suitable for applications where gun-metal is unsuitable.

Hardness.—In this respect S.B. has a definite advantage over gun-metal. The Brinell hardness of S.B. is 100 to 120, as against 75 to 85 for gun-metal.

Corrosion Resistance.—Laboratory tests, confirmed by service results, indicated that S.B. is quite equal to gun-metal in resistance to sea-water and industrial waters.

Shrinkage.—The copper-silicon alloys of this type have a higher shrinkage than gun-metal. Measured on a ¾-in. square bar 12 in. long the contraction is 0.200 in. per ft. The corresponding figure for Admiralty gun-metal is 0.165 and that for manganese brass 0.245 in. The shrinkage of S.B. is hence approximately midway between gun-metal and manganese brass. Foundry experience bears this out, and it is necessary to provide more liberal gates and risers than in ordinary gun-metal practice. The shrinkage of S.B. has proved to be the main obstacle to its wider use. Doubtless difficult designs could be cast in S.B. with suitable precautions, but the cost of putting on and removing large risers neutralises the original price advantage of the metal itself.

Structure.—In the cast state S.B. has a structure consisting of the $\alpha + \beta''$ phases. (Fig.1.) In small castings the general arrangement is dendritic and resembles that of gun-metal. According to C. S. Smith (J.I.M., XL, 1928, No. 2, page 359) the limit of the α phase in equilibrium in a pure copper-silicon alloy is just under 4 per cent. silicon in the cold. Castings of this silicon content, however, when cooled normally, also show some of the β'' phase.

General.

After three years' experience it is possible to assess the usefulness of this alloy. It has been found to have qualities which make it preferred for many of the smaller types of casting. In the liquid state the metal is free-running and clean on the surface, yet it does not penetrate into the mould and cores as does phosphor bronze. The castings have a very attractive appearance and the surface skin is much better than can be obtained from gun-metal cast in similar moulds. Dressing is easy, and the machine shops find that the clean skin is light on tools.

The castings have a slight purple tinge which serves to distinguish them from gun-metal. After machining, S.B. can also be distinguished from gun-metal by a slight difference in colour. In any case of doubt, the Brinell hardness quickly decides the question. The one drawback which militates against more extensive use of S.B. is the shrinkage.

Aluminium-Silicon Alloys.

Silicon gives with aluminium a series of alloys which has proved to be very useful in engineering. The range of silicon content most commonly used is 9 to 14 per cent., but useful alloys are obtained with even lower silicon contents round 5 per cent. The aluminium-silicon alloys have proved to be a very definite advance on those previously used, on account of their excellent foundry characteristics. The shrinkage is low and the metal is relatively free from hot-shortness just after freezing (J.I.M., XL, 1928, No. 2, page 230). As a result, complicated designs can be cast which would be very troublesome in the older types of light alloy. By the free use of chills in the mould, the strength and machining qualities of the alloy are improved and "draws" are prevented by equalisation of cooling rates. Unsoundness caused by trapped oxide films can be avoided by arranging the pouring gates so as to introduce the metal in the quietest manner possible without splashing or swirling. The aluminium-silicon

* Paper presented at the Twenty-Eighth Annual Convention of the Institute of British Foundrymen at Birmingham yesterday.

alloys have served to widen the scope of light alloys, in marine engineering especially, to an extent quite unforeseen even 15 years ago.

Nickel-Silicon and Nickel-Copper-Silicon Alloys.

In these groups, silicon also proves to be a useful addition agent. It may be added direct; the use of an intermediate hardener is quite unnecessary. There is no difficulty in obtaining homogeneous melts if the silicon is about walnut size. The silicon addition assists in deoxidation, and on that account, less magnesium can be used.

Nickel-Silicon.

The effect of silicon on the hardness of nickel is indicated by the following:—

Silicon. Per cent.	Brinell hardness.
0	80
2.8	80
4.3	101
5.9	143
6.8	229

The tensile strength is scarcely affected by silicon additions, but remains in the neighbourhood of 30 tons per sq. in. The elongation falls from 30 per cent. in the case of pure nickel, to about 2 per cent. in the alloy with 6.8 per cent. silicon. Up till now, there has been little call for hardened nickel, but this series may prove to be useful as the demand for nickel castings increases, say, in food handling. If the difficulty of etching microsections can be taken as a guide, the nickel-silicon alloys should possess very good resistance to corrosion. With nickel-copper alloys of the Monel ratio (70 Ni to 30 Cu) the addition of silicon increases the hardness in the following manner:—

Silicon, Per cent.	Brinell hardness.
0	110
1	114
2	128
2.5	150
3	190–220

At 2.8 per cent. silicon an alloy of very interesting characteristics is produced. In the cast state it has the following properties:—Tensile strength, 37 to 42 tons per sq. in., and an elongation of 5 to 15 per cent.

It can be softened by heating to 980 deg. C. for two hours; this brings the Brinell down to 140. Castings may be machined in this condition then rehardened by heating at 590 deg. C. for 1½ hours. They then have the following properties:—

Tensile strength	40 to 50 tons per sq. in.
Yield point	Over 25 tons per sq. in.
Elongation..	15 to 25 per cent.
Brinell	220 to 230.

If the silicon content is increased to 3 per cent. the Brinell hardness, after heat-treatment, is 240 to 260. Even at this hardness the alloy retains ample ductility, the elongation being from 10 to 15 per cent. These silicon-Monel alloys are proving useful in parts subject to severe abrasive and corrosive conditions. They probably represent the highest combination of strength, hardness and corrosion resistance available commercially to-day in the whole range of non-ferrous castings.

Conclusion.

There are many other aspects of silicon which have not been dealt with. These include its general properties as a deoxidising agent, its indirect effect as a controlling element in cast iron, etc., etc. This brief survey may serve to point out its importance in various alloy systems and to indicate possible lines of development of new alloys.

The writer desires to acknowledge his indebtedness to the directors of Messrs. G. & J. Weir, Limited, and Monel-Weir, Limited, for permission to present this Paper.

Pickling—A Cleaning-Room Process.*

By G. H. Cooper.

The process of pickling is an industrial operation used for removing scale and dirt from iron and steel objects by means of an acid bath. The process is utilised chiefly to preserve the surface of the metal for some form of ultimate protective coating. In the steel industries, pickling is used extensively to clean sheets, plates for tinning, strips, rods and pipes, and in the foundry to clean castings for enamelling, galvanising, painting, etc. A considerable tonnage of castings formerly cleaned and prepared for protective coating by the pickling process now undergoes one or more of the various types of sand-blasting.

The scale which is found on the surface of castings consists largely of fused sand. The amount of scale depends upon the chemical composition of the iron and the pouring temperature of the metal. Sulphuric acid, which is used much in pickling steel products, such as sheets, behaves rather peculiarly when brought into contact with the sand scale on the surface of the casting. Pure H_2SO_4 has no effect on either Fe or scale, but dilute H_2SO_4, instead of eating away the scale, attacks the iron. Hydrofluoric acid reacts readily with sand and the scale formed by fusion of sand at the pouring temperature of the iron. Castings are pickled chiefly with this acid. The following is the solution used: 1 part hydrofluoric acid, 1.2 parts hydrochloric acid, and 12 parts H_2O. This solution must remain in a heated condition at a temperature of 130 deg. F. (55 deg. C.), one hour being required to complete the pickling operation.

Another solution is made up from 1 part of hydrofluoric acid diluted to 8 times its bulk with H_2O. Castings may be allowed to stay in the bath any length of time, since the acid only eats away the sand. After castings are removed from the hot pickling solution they should be washed thoroughly in clean hot water.

A wide variety of equipment is used in the pickling process, the design depending upon the class of work to be pickled, the quantity of castings which may be cleaned and the method of procedure to be followed. Pickling tanks are constructed of many different varieties of wood—cypress, yellow pine, white pine and fir being the most common. The *wood* tank may be lined with lead, which is carried up the sides, over the top and down the outside for about 1 ft. The lining is joined together by oxy-acetylene welding, and all sharp corners in the tank are rounded. *Steel* tanks are used for water-rinse tanks, and for alkali solutions (in the enamel industry), and for storing concentrated H_2SO_4. *Rubber-lined steel* tanks, with all pipes and valves equipped with the rubber lining, are used for muriatic acid. *Concrete* pickling tanks, lined with lead or special acid-proof bricks or paving blocks, are also in use. The shell is made of 6- to 9-in. concrete, set on heavy timbers painted with acid-proof asphalt. Pickling tanks may be round, square, oval and rectangular.

Construction of Pickling Tanks.

For small jobs they are made of cypress, dovetailed between the joints and painted, or sealed with red lead, white lead, rubber or acid-proof cement. The rods, nuts and washers are made chiefly of bronze. The bottom of the tank is protected from wear by a layer of bricks and the tops are protected by cypress planks, nailed or bolted with copper spikes or bolts. These tanks may be heated with an open steam-line or copper system. A common method is to have a rubber hose connection, a copper pipe, an acid-proof (steel) nipple, to pass steam directly into tank. The chemical action during pickling causes gases to be generated. Fumes are allowed to pass through windows. Inhibitions are used to reduce the amount of gas produced.

Various types of equipment are used to dip the castings into the pickling solution. These include hooks, bars or pipes which hold the castings on numerous hooks, and in turn support the castings, chains for heavy castings and hangers for baskets.

In one foundry, which makes cylinder castings for the textile industry, the castings are taken to the cleaning room by a trolley hoist. Then they are lowered into a long, shallow trough filled to a depth of 3 in. with the pickling solution. Each casting in turn is rolled from one end of the vat to the other, the surface of the castings being submerged about twenty-five times during the operation.

* A Paper read before the Lancashire Junior Section of the Institute of British Foundrymen, Mr. H. V. Grundy presiding.

Company Meeting.

William Beardmore & Company, Limited.—Mr. H. A. Reincke (chairman and managing director), presiding at the annual meeting of Messrs. William Beardmore & Company, Limited, said that the shipyard was sold to the National Shipbuilders Security, Limited. In view of the discontinuance of Admiralty orders as a result of the policy of disarmament, and, indeed, the lack of orders for ships which could be constructed without loss, the directors decided that they had no right to incur heavy and inevitable losses which would cripple the resources of the company and so restrict its endeavours in directions which held greater promise of ultimate success. The mere closing down of the shipyard and awaiting better times would have resulted in continuing losses on standing charges, as well as involving expenditure on re-equipment which would become necessary at that distant date, which no one could foresee, when conditions would be such that the demand for new ships would justify the reopening of the yard. The alternative was to seize the opportunity which arose to sell the yard at a price which, in addition to its break-up value, provided some compensation for the contribution made to the industry as a whole by the elimination of competition of a yard of the size and importance of Dalmuir. The locomotive department at Dalmuir also had been closed down, though not disposed of. The department had worked continuously at a loss from the date of its inception, and, rather than seek to obtain orders which, in the present state of the locomotive industry, would be bound to result in further substantial losses, the directors decided that it would be a sounder policy to close the department. Whether or not the closing down of this department would prove to be of a temporary or of a permanent nature must depend upon the future of the locomotive industry, which was at present suffering badly from the fact that the productive capacity of the country was in excess of the demand. The policy that had been pursued and that would be pursued in the future was to take whatever step might be necessary towards the elimination of sources of loss and the ultimate strengthening of the main centres of the activity of the company. Of these main centres there were two at Parkhead and one at Dalmuir. The steelworks came first. They were the foundation on which the company was built. The forge at Parkhead was working, while the Mossend Works had been closed since 1928. All that he could say at present with regard to the Mossend Works was that while they continued to remain closed they must be a factor in any scheme of rationalisation in the Scottish steel industry. At Parkhead there had been during the year a trading loss of roughly £29,000, which, while it was greatly to be regretted, could not be avoided in the present state of trade depression. Much work had been done at Parkhead to improve the equipment of the works, and economies had been introduced which had materially reduced the cost of production, but the dearth of orders deferred the day when the benefit of these improvements would be reaped. The forge and the foundry, which were the principal departments at Parkhead, had done better than last year. In the Diesel engine department a great deal of work had been done in developing and improving design. When the shipyard was closed down it was decided to carry on the marine-engine department as an independent unit. Last year 19 sets of exhaust steam turbines and gears of the Bauer-Wach system had been installed in vessels of a total indicated horse-power of 110,000.

Some Considerations and Tests for Cast Materials for High-Temperature, High-Pressure Service.*

By L. W. Spring, Chief Chemist and Metallurgist, Crane Company, Chicago, Ill.

[AMERICAN EXCHANGE PAPER.]

As is well known, the casting industry is an old one, cast irons apparently dating back from the fifteenth century, when the blast furnace produced high carbon-content iron. Malleable iron began with Réaumur, in 1722, in France, and a separate industry, based on blackheart iron, developed independently by Seth Boyden in New Jersey, U.S.A. Cast steel, apparently, was made first by Huntsman, in England, who found that he could get a more uniform mixture by melting cemented shear-steel in a crucible.

From these beginnings, castings of grey iron, of so-called semi-steel, chilled iron, malleable iron, carbon and alloy cast steels, and a multitude of brasses and bronzes, have been developed to a high state of perfection. In recent years these have been followed by the newer nickel-copper alloys, such as Monel metal, tin-nickel-copper alloys for greater hardness, silicon-copper,

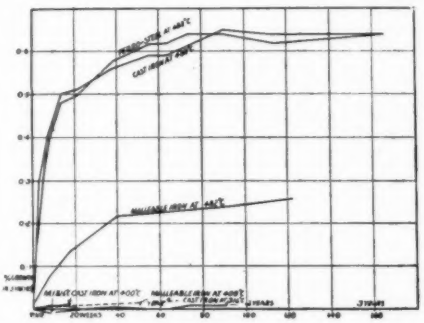

FIG. 1.—LINEAR GROWTHS OF THE CAST IRONS ON PROLONGED HEATING.

and steels of nickel-chromium, chrome-molybdenum, chrome-tungsten, and various others of the more highly corrosion-resistant type.

While the casting industry has developed commercially to gigantic size, castings of a large variety of shapes and sizes being available for various purposes, other products, forgings, stampings and welded product, some of them made by methods scarcely known even ten years ago, have come in to help take care of the multitudinous needs of present-day industry. The revolution has not been confined to this, but it has had a much larger scope, involving also, apparently to a much greater extent than before, the attitude of people toward life, toward fulfilment of desires, personal or otherwise, and especially in the willingness to pay liberally for the fulfilment of these desires. The increased leisure resulting from the use of machinery to do much of what formerly was done by manual labour has increased the means for employing leisure, such as the automobile, the cinema, the wireless, etc.

More Severe Conditions of Service.

A new factor, or rather one that has become magnified, has pushed development, and at the same time has made somewhat uncertain for the time being the status of some of these products —castings, forgings, welded assemblages, etc. This factor is the higher temperatures desired for the chemical and mechanical processes which to-day are so much more efficiently making steam and electrical power, petroleum products for our motor-cars, tractors and other machines, coke for smelting of materials, etc. While temperatures have been raised from approximately 260 at the opening of this century to 400 deg. C. for steam plants and up to 480, 590 and even 980 deg. C. for oil-cracking and chemical-process work, accompanying pressures have gone from 100 and 200 lbs. per sq. in. to 600 and 1,500, and even 3,100 lbs. per sq. in. is being tried.

These higher temperatures and higher pressures, which have come upon the industrial world with some suddenness, properly have brought about an increased caution with regard to the materials which are used for the more strenuous service. This increased caution also results be-

MR. L. W. SPRING.

(A Biography of Mr. Spring was printed in our last issue.)

cause of the larger pipe lines and pressure containers used than formerly, which, if seriously leaking or broken, would release such immense amounts of steam, oil or other fluid, that results would be highly disastrous. Whilst without any doubt there have been defective materials, such

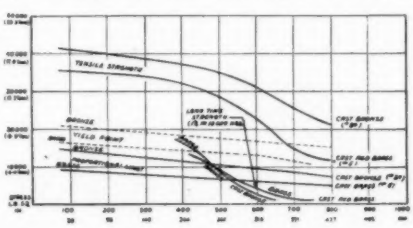

FIG. 2.—COMPARISON OF STRENGTHS OF CAST BRONZE AND CAST RED BRASS.

Short-time tensile strength and proportional limit show the bronze to be the stronger. However, long-time, high-temperature tests indicate that above 250 deg. C. the red brass is more creep-resistant than the bronze. Each curve is the average of two groups of tests.

as laminated or scabby tubing, castings of excellent appearance which, however, contained blowholes, sand inclusions, shrinkage spots, etc., few failures have resulted, since there usually has been sufficient strength and ductility, either or both, according to circumstances, to maintain a proper factor of safety. Of course, castings usually have been designed with this matter of excess strength in mind, thus providing ample security.

Undoubtedly, the higher temperatures and pressures which are being used have overawed designing and operating engineers, who, in a very proper effort to insure safety in operation, have demanded perfection in castings. The recent development of the X-ray method of testing, and, to a certain extent, the magnetic and the Sperry methods, along with the "marvellous" development of welding "advertising," temporarily at least, have put even steel castings at a disadvantage. It would appear that, taking castings of the high development and integrity as they stand to-day, if as conscientious and vigorous a campaign had been waged by casting manufacturers as has been put on by the advocates of forgings, of rolled products, and sections built up by welding, the present high-grade castings would not be in the somewhat disadvantageous position in which they find themselves at the present time. While difficult problems are encountered and natural laws of metal cool-

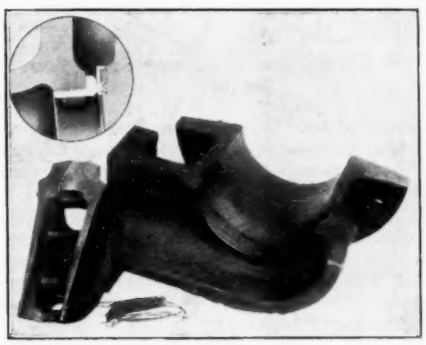

FIG. 3.—CAST-STEEL GATE VALVE FROM WHICH THE NICKEL-COPPER ALLOY SEAT AND DISC RINGS WERE DISSOLVED AND THE STEEL BADLY CORRODED IN TWO YEARS ON 100 LBS. PRESSURE, 371 DEG. C. TOTAL-TEMPERATURE CRACKING STILL.

ing, solidification, shrinkage, grain formation, etc., still operate, the foundry product of to-day has been brought to a very high quality from the standpoint of operating permanence and safety. The welded product, too, is subject to the working of untoward natural laws, so the welding expert has his troubles and often his unsatisfactory product. Forgings and rolled products are in much the same category as to the possibilities of flaws and weakness, and they usually have further disadvantage in the way of lower resistance to surface corrosion, lower yield-point, and lower resistance to creep at high temperatures. Thus it would appear that the castings industry awaits a champion.

Early Conditions and Metals.

Up to the beginning of the present century, cast-iron valves and fittings were in very general use in steam-power plants, in oil refining, and other chemical service. Steam pressures and temperatures then were not higher than 400 lbs. per sq. in. and temperatures were 195 to 230 deg. C. Distillation of petroleum in those days, which was before the present-day high-pressure, high-temperature cracking process, usually required less than 100 lbs. per sq. in. pressure. With the desire for increased efficiency, the heretofore-used saturated steam came to be conducted away from its contact with the water in the boiler and was given further heat in a separately-fired vessel, or tank of tubes, whereby the mechanically-entrained water which saturated it was vaporised and the whole was given an additional 50 deg. C. of heating, making total

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* Paper presented at the Twenty-Eighth Annual Convention of the Institute of British Foundrymen at Birmingham yesterday.

temperature of approximately 285 deg. C. While many of the old installations of steel pipe and cast-iron valves and fittings were able to continue service as before, occasionally it was found that the cast iron distorted under the higher heat and sometimes increased in overall dimensions or more or less mysteriously failed otherwise. For these reasons and because the trend in temperatures and pressures still was on the up-grade, it came to be deemed prudent to use a product which insured greater security, so, during the first decade of this century, there was considerable agitation for the use in new installations and the replacement in certain of the old plants with steel for use at the higher temperatures. While cast iron was an excellent metal from the foundrymen's production standpoint, being easy to melt and to cast, of comparatively low cost, etc., the change gradually was brought about until, with recent and present-day steam

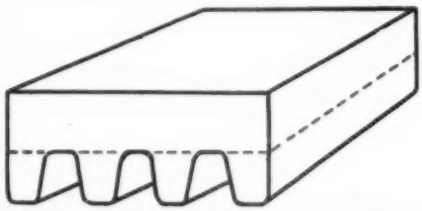


FIG. 4.—METHOD OF CASTING STEEL TEST-SPECIMENS.

pressures of 600 lbs. and 1,500 lbs. respectively and temperatures of 400 and 435 deg. C., cast iron has become a thing of the past for these particular applications.

To be more specific, it has been known, since Outerbridge first showed it nearly twenty years ago, that cast iron grows in volume sometimes 40 per cent. when kept for a time at red heat (Fig. 1). There has been question in the minds of some regarding the growth of cast iron at

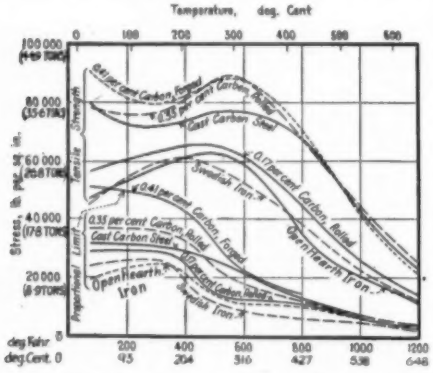


FIG. 5.—COMPARISON OF SHORT-TIME TENSILE STRENGTHS AND PROPORTIONAL LIMITS OF SOME METALS TESTED.

temperatures as low as 400 deg. C. While there are cases at this low temperature which seem quite authentic, it is definite that growth does occur at 480 deg. C., of 1 to 2 per cent. of its original volume. In one case, a cast-iron valve came back to the manufacturers, after service in a steam plant, $\frac{3}{8}$ in. longer, face to face, than it went out. While perhaps this could not have been proved on the witness-stand or to the satisfaction of a scientific man, there was no question in the minds of those familiar with the circumstances that this enlargement had taken place. Since that time, in the author's laboratory, test was made over a period of 165 weeks at 480 deg. C. temperature, in which a bar of ordinary soft cast iron 5 in. long grew gradually 0.032 in., or 0.64 per cent., in length during the period stated.

While cast iron is generally known as a good heat-resisting material with reasonably low oxidation and distortion under heat, it is a fact that at the lower temperatures, probably due to penetration of air and gases and the oxidation of some of the silicides, and of some of the graphite to carbon dioxide, cast iron does deteriorate. Steel is much less subject to deterioration than is cast iron.

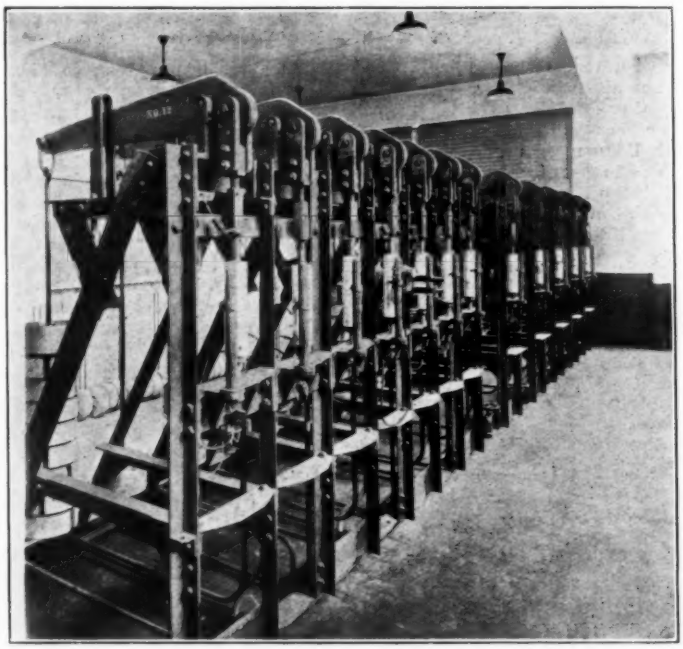


FIG. 6.—TWELVE MACHINES IN SERVICE FOR THE MEASUREMENT OF FLOW IN METALS AT VARIOUS TEMPERATURES.

It is not proposed to deal at any great length with cast iron, the brasses and bronzes, nor with malleable iron, since they hardly are high-temperature, high-pressure materials. Since the hazards of modern industry are so much greater than formerly, stronger and more dependable material is readily available. First cost of higher-price materials is not so important as formerly, and cast steel has become quite largely standard equipment.

Special Cast Irons.

Mention should be made, in passing, of the special cast and malleable irons. Because of the upward trend in way of heavy duty and much more severe operating conditions, certain modified cast-iron alloys have appeared within the last few years. In North America, business has not been good for the cast-iron foundry or the malleable-iron foundry, and these have seen the business going to the steel casting, the steel forging, steel stamping, welded product, etc. Instead of cast iron, therefore, with 8 to 11 tons per sq. in. tensile strength, so-called "semi-steel," with 15.6 to 17.8 tons per sq. in., there now are available a series of perlitic cast irons with anywhere up to 31.2 tons per sq. in. and

FIG. 7.—INDIVIDUAL CONTROLLERS, RHEOSTATS AND RELAYS USED IN MAINTAINING CONSTANT TESTING TEMPERATURE.

malleable irons which have been perfected until the 15.6 tons per sq. in. of some years ago has risen to 24.5 and 29 tons or more per sq. in. with 20 to 25 per cent. of elongation in a 2 in. length. Some recent cast irons for special purposes and wear resistance, yet avoiding the white iron of the chilled product, have as high as 42.4 and even 44.6 tons per sq. in. Castings from low-carbon irons are made slightly grey

by the addition of ferro-silicon, calcium silicide, etc., with careful regulation of carbon, manganese and sometimes molybdenum or nickel content. Because of these various processes and products, there is no such distinct division between the cast irons, malleable irons, etc., as formerly obtained.

Non-Ferrous Alloys.

The non-ferrous metals, mainly the brasses and bronzes, were used in the early days for low-temperature and low-pressure service. However, these non-ferrous alloys lacked strength, particularly as the temperature rose beyond 260 deg. C. and the possibilities of inter-granular changes of the zinc-copper, tin-copper, or either combination, increased. These, together with the low-melting point and inclusions of lead, made the brasses and bronzes losing competitors in the race for preference. It has been learned since that there are changes in the metal around 260 or 316 deg. C. which unfit the cast alloys, the

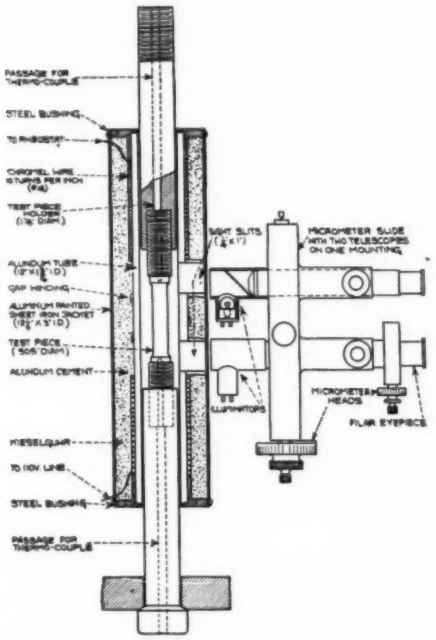


FIG. 8.—CONSTRUCTION AND ARRANGEMENT OF FURNACE, SPECIMEN AND TELESCOPE.

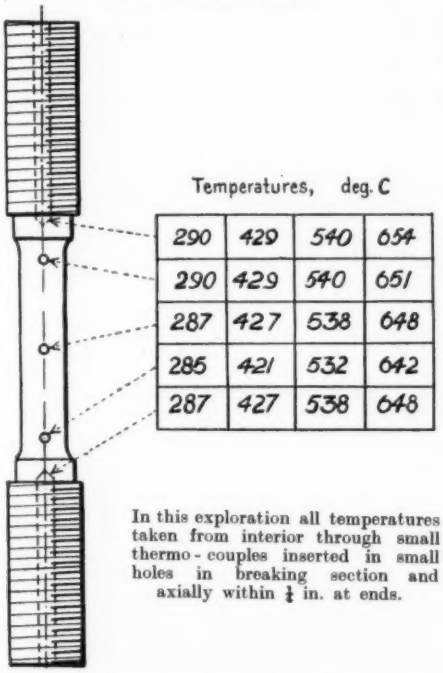
red brasses and bronzes, for service at high temperatures, whereas the yellow or high-zinc, brasses, either in cast or the present-day forged condition, apparently are not particularly satisfactory even as high as 260 deg. C.

The tin-copper bronzes always have occupied a preferred position among non-ferrous cast metals. It would be interesting to read the future in this regard. While, as shown in Fig. 2, the short-time high-temperature test substantiates the claim of the tin-copper bronze alloys to the premier position, the "creep" test reverses the alignment, awarding the first position to the brass of lower-tin and lower-copper content. This is somewhat difficult to understand when one considers that the lead sweats out and the high-zinc alloys do not withstand high-temperature service well. This is likely because of some instability of the tin-copper compound, which at the lower temperature gives the increased hardness in the case of the tin-copper bronzes. Ordinary manganese-bronze with 40 per cent. zinc makes quite an unsatisfactory showing even in the short-time high-temperature test, and it is not safe to use the rolled equivalent or forging brass at temperatures much above 260 deg. C. A steam test was made at 300 lbs. pressure and 316 deg. C., using an experimental thin-walled forged brass ring. Its low resistance at 316 deg. C. allowed the ring to unfold until the centre-piece which carried the stem and disc blew out. The higher temperatures, and particularly the chemical corrosion, of oil-distillation equipment make brass material inadvisable except for use in auxiliary equipment in the oil refinery. Aluminium-bronze does resist quite well chemically, and some is used on oil-cracking, particularly as forgings.

COMPARISON OF WEAR OF FORGED BRASS WITH CAST BRASS.*

Lubricated, cold, 2,000 *lbs. per sq. in. load.*	Loss in Mg.
Forging brass vs. forging brass ..	15
Naval bronze vs. naval bronze ..	2
Cast red brass vs. cast red brass ..	0.1 to 0.4
Cast bronze vs. cast bronze ..	0.2 to 0.3
Tested in Steam at 316 deg. C., 500 lbs. per sq. in. load.	
Forging brass vs. cast brass—loss on forging brass	800 to 5,000 mg.
Forging brass vs. cast bronze—loss on forging brass	800 to 5,000 mg.
Cast red brass vs. forging brass—loss on cast red brass	10 to 17 mg.
Cast bronze vs. forging brass—loss on cast bronze	1 mg.

* See Fig. 23 and Table I.



In this exploration all temperatures taken from interior through small thermo-couples inserted in small holes in breaking section and axially within ¼ in. at ends.

FIG. 9.—EXPLORATION BAR FOR TEMPERATURE VARIATION, SHOWING TEMPERATURES TAKEN SIMULTANEOUSLY AT DIFFERENT POINTS IN THE TEST-SPECIMEN.

Excessive Corrosion.

The nickel-copper alloys which served so well in valve trim under the lower temperatures and pressures used some years ago, have been found to be rather too soft and subject to scoring or galling where surfaces slide against each other under heavy pressure. Also they were not found to be good in the high-sulphur gas atmosphere in oil-cracking equipment. A recent case at issue was shown by a call from a refinery which had installed, on each still, two extra cast-steel valves with alloy seat- and disc-rings of approximately two-thirds nickel and one-third copper. These two valves were used simply for safety. They were so located that, should a fire occur either in the pipe still which was handling the oil to be cracked, or the tower or vapour end which condensed and separated the distillates, the valves could be closed to avoid extension of the fire. During the two years in which the still was in use there had been no occasion to close the valves, and upon dismantling the still and examining the equipment it was found that neither of the two valves had the disc-rings or seat-rings intended to seal the valves upon closing. The threads into which the rings had been screwed appeared to be intact and the recesses in the disc into which the disc-rings were locked were empty, as shown in Fig. 3.

At first sight it appeared that these valves never had had seat- and disc-rings, but both the manufacturer and the user knew that originally they had. Finally, digging at the bottom of some of the threads, small particles of the nickel-copper alloy were found, proving that the rings had been dissolved in the two years and had gone along with the gasoline. This illustrates what most of the producers of castings and equipment for chemical industry now know; that is, that because a valve or casting is good and of high grade for one purpose, it is not necessarily so for another service. To-day valve trim of the straight chrome stainless irons containing 12 or 13 per cent. chromium and less than 0.12 per cent. carbon, also the well-known 18-8 metal (chrome-nickel alloy), as well as two or three other compositions, are quite successfully serving the purpose.

Of course, from the high-temperature standpoint, of electric-power generation, of oil-refining, and of some of the chemical industries, steel is the important material. It has high strength, high elastic properties and ductility, with singular lack of fragility. With pressure and temperature requirements advancing by leaps and bounds, this lack of fragility, in other words,

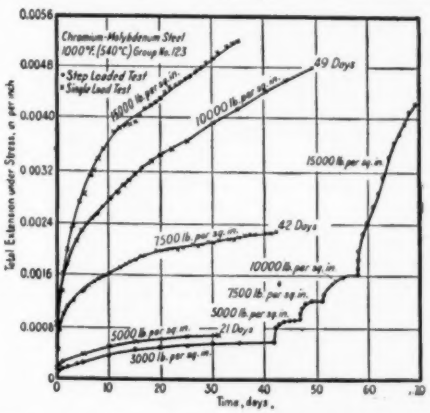


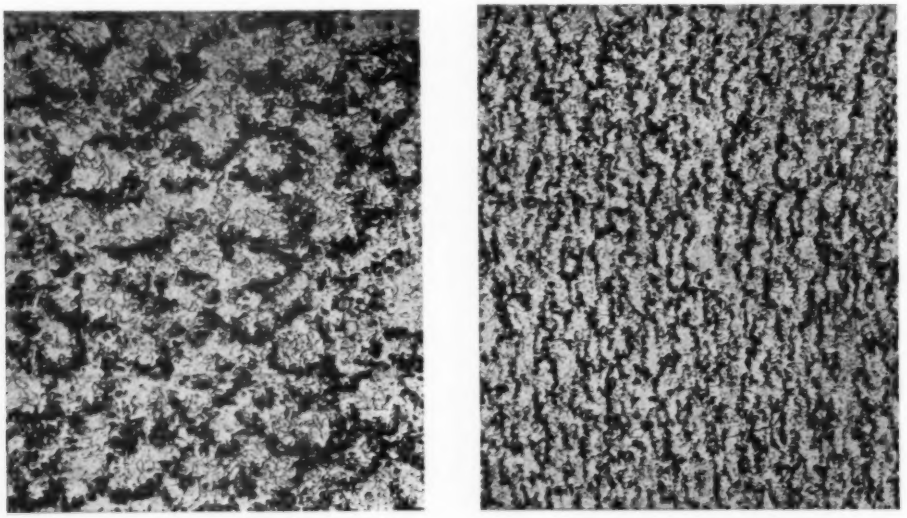
FIG. 10.—FLOW-TIME CURVE FOR STEP-LOADED SPECIMEN OF CHROME-MOLYBDENUM CAST STEEL COMPARED WITH FLOW-TIME CURVES OBTAINED USING A SEPARATE SPECIMEN FOR EACH LOAD.

toughness, is a very important asset. Even hot oil-lines in the oil refinery under quite low pressures, which originally were equipped with cast-iron valves and fittings, have been changed over to steel, oft-times due to a single experience with a disastrous fire, because a cast-iron fitting was unable to resist the stress due to thermal expansion, shock, or of improper support of a long line of pipe.

Steel.

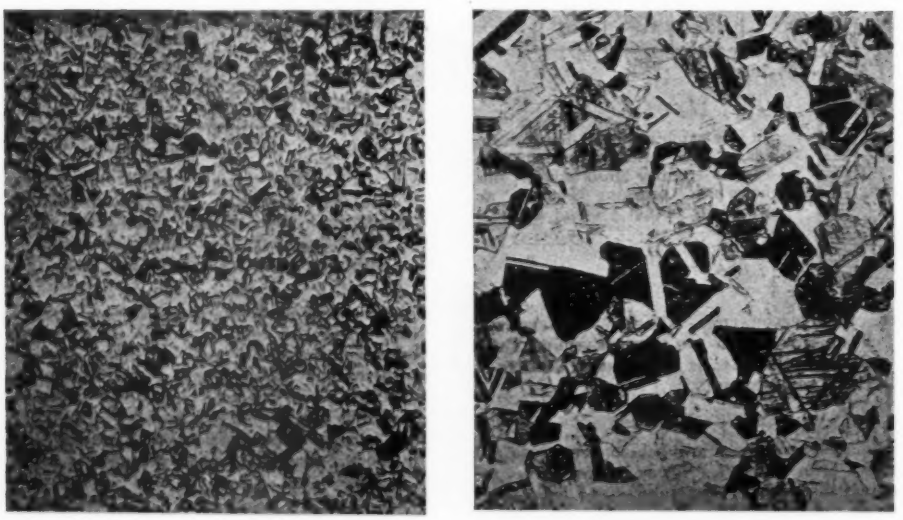
For a long time carbon-steel castings with steel piping were considered satisfactory for power houses, oil-refining plants and others. A number of years ago alloy cast steel began to be found highly desirable, due to its greater strength and elastic limit, also to its finer grain and better resistance to corrosion. As temperatures increased, carbon-steel tubes were found too short-lived, and 18 per cent. chrome tubes with 0.12 to 0.20 per cent. carbon were used for a time. Its high strength accompanied a high resistance to corrosion. This alloy, however, proved to be rather unstable, at least in the particular range of 427 to 538 deg. C., at which superheater tubes and oil-cracking equipment were run. As now is well known, brittleness developed apparently when cold, though not at the operating temperature of 482 deg. C. This material apparently has been entirely withdrawn from the market for 482 deg. C. service or thereabouts. While the 12 per cent. chrome with

0.12 per cent. carbon or below apparently has never shown any tendency toward brittleness, it has been displaced to a considerable extent by the well-known 18-8 metal, which has even higher resistance to corrosion. Lately some of this 18-8 metal has been put into tubes for steam operating even as high as 538 to 648 deg. C., also as cracking tubes in 482 deg. C. oil-cracking furnaces. These applications also include castings of 18-8 material, with carbon content all the way from less than 0.07 per cent. up to 0.20 or even 0.35 per cent. Definite information as to castings is lacking to a considerably greater extent than in the matter of tubes, for the manufacture of a few of these castings has been accomplished by each of various foundries. Some of these lacked full equipment and some had not facilities for determining and correlating information sufficient for systematic manufacture. The purchaser also had not always known exactly what he wanted and, therefore, had changed his specifications more or less with each order.



(A) Cast, Annealed. (B) Forged, Annealed.

A 0.20 per cent. Carbon Steel, etched with 5 per cent. Nital. × 50.



(C) As Rolled. (D) Water-quenched from 1,150 deg. C.

Austenitic Nickel-Chrome Steel (18-8), etched with Aqua Regia. × 100.

Fig. 11.—Microstructural Differences Affecting Creep.

Two different types of steel are represented, with comparatively coarse and fine grain size. The coarser-grained material in each case is the more resistant to creep at temperature above the equi-cohesive temperature.

Specimens for Accurate Testing of Cast Steels.

It is unfortunate that physical-test results from different foundries are not as comparable as are similar results from different steel mills. The latter, of course, record physical tests made on rolled bars. Rolled bars do not vary so greatly because of their quite uniform grain, even though the casting temperatures of the ingots, the discard, the amount of reduction from ingot to test-specimens, the temperature of rolling, etc., differ considerably.

Presumably it is not to be wondered at that able metallurgists, who have been affiliated only with rolling mills, should overlook the difficulty of obtaining uniformity in cast test-specimens. For obtaining a considerable number of like test-specimens for extensive investigation, a cast-steel plate which can be cut up naturally suggests itself. It seems not to be as generally known as it should be that provision must be made for generous feeding to take care of natural internal shrinkage, to ensure solidity and thorough uniformity. This is a difficult matter, but unless such precaution is taken the plate will not give concordant or representative results when cut up into test-specimens. A plate is not a good pattern to provide uniform specimens.

As stated, comparatively little attention seems to have been paid to the design of test-specimens of cast steel, to their proper feeding with molten metal during solidification, which, of course, means gating, risering, etc. While the steel foundries to a considerable extent have come to cast their test-specimens underneath a feeding block, it has not been a universal practice. Even so, there is no standard design or standard method of feeding test-specimens among foundries, except on orders from a few customers such as the U.S. Navy, which does specify shape and size of test-bar, feeding block, etc.

Naturally, there are two considerations in the making of test-specimens. The formerly-

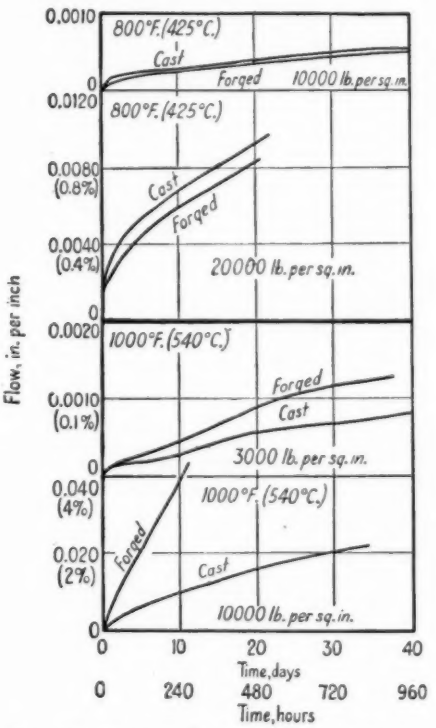


Fig. 12.—Flow-Time Curves for 0.20 per cent. Carbon Steel. Comparison of Annealed Cast Steel with Annealed Forged Steel of Identical Analysis.

favoured one seemed to be that the test-specimen shall represent the casting, that is, give the same properties as test-pieces cut from the casting itself. The other is that the test-specimen shall represent, very definitely, the quality and strength of the metal which goes into the mould. As to the first, manifestly a complicated casting itself does not have the same strength and ductility in different sections such as thick and thin. A cast of steel may be perfect, but if poured into a large section without a riser to ensure solidity, a test-bar, cut from the centre of such section, will show very poor physical properties. On the other hand, a well-fed section, and particularly a thin section of the casting which solidifies early, has excellent physical properties. Cast-on or attached test-blocks, to be removed from the casting, do indicate the annealing or heat-treatment which the casting has had, but they do not give reliable data concerning anything, but the test-block itself or parts of the casting adjacent to it. Hence, it seems wise to adopt the alternative and cast regularly the test-blocks separately, using always identical pattern, gating and closely-controlled temperature. These test-blocks

(Fig. 4) can be depended upon to give information regarding the finished cast of molten steel in the ladle. It is up to the foundryman to make the best use possible of this standard metal. Co-operative work between the foundryman and the laboratory, through cutting up an occasional steel casting and testing various thicknesses of metal from various locations, soon teaches best use of the metal. The use of X-ray or Gamma-ray quickly shows whether shrinkage cavities, sand inclusions or other defects are present, but metal, which is none too solid, can appear sound to the X-ray and even to the eye, and with lower elongation than properly-fed sections of castings or separately-cast test-blocks described. It seems to be more desirable, therefore, to adopt the latter expedient of casting identical test-blocks from each heat, and at least be sure of one of the two possible variables—the heat itself or the casting which is made from it.

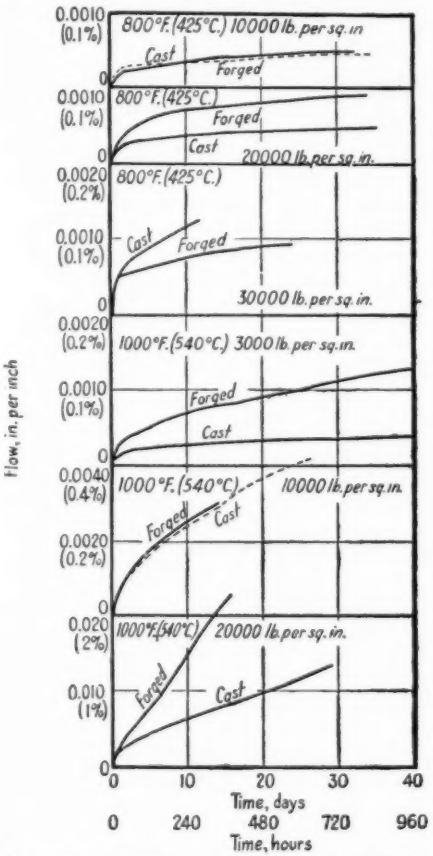


FIG. 13.—FLOW-TIME CURVES FOR NICKEL-CHROMIUM STEEL (2 PER CENT. NI, 0.87 PER CENT. CR, 0.41 PER CENT. C.). COMPARISON OF HEAT-TREATED ALLOY CAST STEEL WITH HEAT-TREATED ALLOY FORGED STEEL OF IDENTICAL ANALYSIS.

In the making of test-bars in sufficient number for high-temperature testing, it is necessary that every precaution be taken to ensure thoroughly- and equally-fed test-specimens, for the cost of testing high-temperature specimens, particularly for creep, is high, and the results are almost worthless if the integrity of any bar of a set is doubtful.

In the developing of test-bars for the author's personal work, a great deal of experimenting was done with the object of obtaining the most typical results for the metal, results that could be depended upon for uniformity and reproducibility. The test-block (Fig. 4) was determined upon and has been used with considerable satisfaction for many years. True, it does not yield a long test-piece, but the 7-in. long blocks have been used satisfactorily for hundreds of creep test-bars. Undoubtedly somewhat greater lengths could be made in this manner without serious detriment to uniformity, but the 7-in. bar generally has been sufficient.

Tests at High Temperatures.

The results of short-time tensile tests at high temperatures (Fig. 5) have been quite thoroughly discussed by us[1] and by many other[2 3].

Flow or creep tests (Figs. 6-14) have given quite important information during the past few years. It seems to be quite well proved that a cast structure will resist without deformation a somewhat higher temperature at the same load, or, what is practically the same thing, a higher

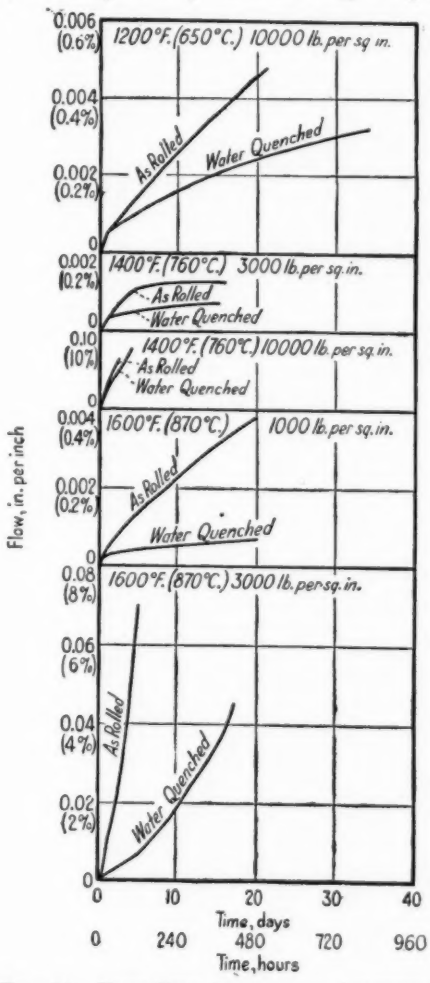


FIG. 14.—FLOW-TIME CURVES FOR AUSTENITIC NICKEL-CHROMIUM STEEL (18-8 ALLOY, 0.4 PER CENT. CARBON). COMPARISON OF THE ALLOY AS ROLLED AND AS WATER-QUENCHED FROM 1,150 DEG. C.

load at the same temperature, than the same material in the forged or rolled condition. This is a comparatively new aspect,[4] and full consideration has not been given to it, nor adequate explanation forthcoming. It appears that above the so-called equi-cohesive temperature, *i.e.*, the temperature above which strain-hardening ceases, slip, once started, as by rolling or by forging, is easier to carry on than it was to start initially. Castings, of course, usually have a coarser grain than rolled or forged material, particularly when of the martensitic type. While this naturally larger grain of castings may be part of the explanation of the greater resistance of castings to creep, it apparently is not a sufficient explanation. Castings which have been annealed usually resist creep better than the same castings which have been normalised or quenched and drawn, *i.e.*, higher stresses are required to produce creep, thus showing again the effect of the larger grain size.

Austenitic Alloys Show Large Grain and Possess High Creep Resistance.

In the austenitic alloys, quenching usually produces large grain instead of fine grain (as shown in Fig. 11), this being opposite to the effect in the martensitic steels. Here results are reversed, so far as creep is concerned; in this case the quenched materials, *i.e.*, the large grain size, resist creep better than the unquenched or small-sized grain material. Further substantiation of these findings is being sought by the Joint Research Committee (A.S.T.M., A.S.M.E.) on the effect of temperatures on the properties of metals, and it is hoped that information from this source will be forthcoming shortly. If these further tests substantiate fully the statements made above, an explanation of the mechanism should prove very interesting.

What effect all this may have eventually on the heat-treatments of castings which are to be used for service in which creep may take place, of course, is problematical. The question is, whether for service at very high temperature,

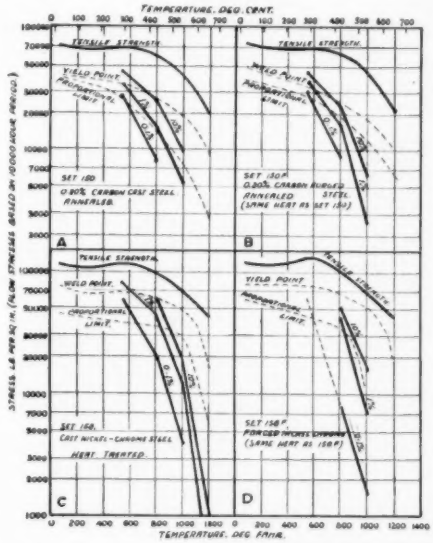


FIG. 15.—STRESS-TEMPERATURE CURVES FOR LONG-TIME AND SHORT-TIME TENSILE TESTS OF CAST AND WROUGHT STEELS.

the engineer always will want steel castings annealed so drastically as to give the finest grain. Heretofore, engineers, steelmen, and others have admired greatly steel fractures which exhibit very fine grain. Now that one is confronted with quite high temperatures, it may become a question whether for such service one should anneal castings more than sufficient to relieve internal stresses. While homogeneity and small grain size is an advantage from some standpoints, and undoubtedly is from the standpoint of former operating conditions, it may not be desirable for all purposes.

Strength *versus* Excess Ductility.

A change of viewpoint quite analogous to the question suggested above came about a few years ago in the bolting, which is used in the high-temperature fields of steam-station and oil-refinery service. The constructional engineer, for bolting, used to demand 25 to 28 per cent.

1 Bregowsky and Spring, "Effect of Temperatures on Physical Properties of Some Alloys." International Association for Testing Materials, 1912; also "The Valve World," January, 1913; also L. W. Spring and J. J. Kanter, "Accuracy in High-Temperature Testing of Materials," "Power Magazine," September 1, 1925, "Valve World," December, 1925.

2 See a Bibliography on "Effect of Temperature on Properties of Metals," compiled by "Joint Research Committee (A.S.T.M. and A.S.M.E.) on Effect of Temperature on Metals," "American Society of Mechanical Engineers' Publication, 1928."

3 Rudeloff, M., "Influence of Increased Temperature on the Mechanical Qualities of Metals," "Proceedings International Association Testing Materials, 1909."

4 "'Long Time' or 'Flow' Tests of Carbon Steels at Various Temperatures, with Particular Reference to Stresses below the Proportional Limit," Kanter and Spring, "Proceedings of the American Society for Testing Materials," June, 1928, and June, 1930; also "Valve World," August, 1928, and December, 1930.

elongation in a length of 2 in. As pressures increased, stresses put upon the pipe lines eventually became so great that, with the 26.7 tons per sq. in. tensile strength carbon-steel bolts then in use, there was not sufficient room in the bolt circle around the flanges which connected valves, fittings and pipes, to allow enough bolts to hold the pressure. Consequently, the bolts used soon stretched. The manufacturer thereupon furnished bolts with 46.8 tons per sq. in. minimum yield point and 55.7 tons tensile strength, but with only a corresponding 16 or 18 per cent. elongation in 2 in.

Naturally, the engineer cannot attain the maximum value in all characteristics on a given material. It has been long known that, with steels, the higher the tensile strength and elastic limit, the lower the accompanying elongation and reduction of area, *i.e.*, the ductility. The object was that, if the yield point or beginning of first slight stretch was put sufficiently high that it would not be reached, the bolt, therefore, could not stretch, and what, then, was the advantage of 25 per cent. stretch capacity over 16 per cent. stretch capacity? It was necessary to make sure,

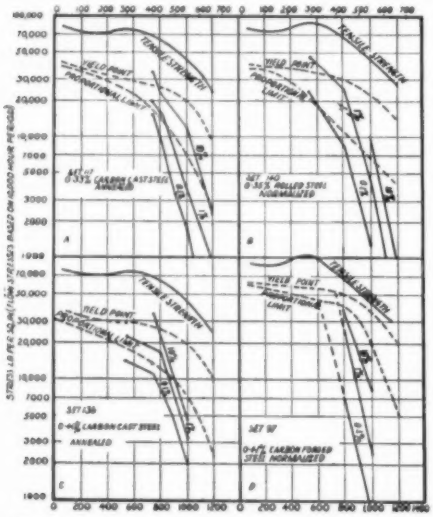


FIG. 16.—STRESS-TEMPERATURE CURVES FOR LONG-TIME AND SHORT-TIME TENSILE TESTS OF CAST AND WROUGHT STEELS, ANNEALED AND NORMALISED.

of course, that the higher-strength steel is not so much harder to be brittle in any way. The use of such bolts now is standard practice practically everywhere for greatest stresses, and engineers have come to see that extreme ductility has disadvantages, and a stiffer bolt is preferable.

Do Steels Deteriorate under Stress and Temperature?

Tests made at normal temperatures, and also short-time high-temperature tests made on test-specimens which had been used in the creep test during which they had been subjected to temperatures up to 538 deg. C. for periods of 1,000 hrs. or more with small amounts of creep during that time, gave practically equivalent results with duplicate specimens (identical heat of steel, identical treatment) which had not been so tested. Table II gives very interesting information. For instance, Group 2 shows that 0.33 per cent. carbon steel, after 1,672 hrs. test in creep at 400 deg. C., while loaded to 15,000 lbs. per sq. in. (6.7 tons), with total creep of 0.09 per cent., gave practically the same results on subsequent short-time tests at 400 deg. C. as did an untested duplicate bar. In Group 1, 0.33 per cent. carbon, again after 1,008 hrs. of creep testing at 538 deg. C., 4,000 lbs. load, with total creep of 0.21 per cent., gave 19.1 tons per sq. in. yield point, while duplicate untested bars, also tested cold, gave 19.4 tons yield point. Another bar from this lot, which had been in creep test at 400 deg. C. for 1,008 hrs. at 13.3 tons load, with 4 per cent. total stretch in 2 in., gave 24.0 tons yield point. Elongation and reduction of area of these samples gave results expected, when it is realised that 400 deg. C. is within the strain-hardening range, and the yield point, therefore, ought to be expected to be higher, while elongation and reduction of area naturally are lower. The same explanation holds good for Group 2, just spoken of. In Groups 3, 4 and 10 it is seen that very long creep-testing periods in general tend to produce an annealing effect in which the tensile strength is somewhat lowered and the elongation raised. While 427 deg. C. is within the strain-hardening range,

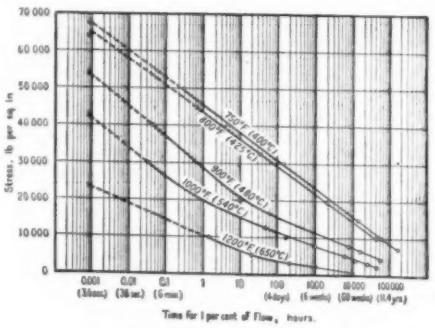


FIG. 17.—RELATIONSHIP BETWEEN LOAD AND TIME TO PRODUCE 1 PER CENT. OF FLOW IN ANNEALED CAST CARBON STEEL AT DIFFERENT TEMPERATURES.

When short-time tensile strengths are plotted against the time ordinate for 1 per cent. of flow at pulling speed (3 secs.), and are connected to the load-time graphs, the curves appear continuous.

the amount of flow resulting from the 4,032-hr. test in Group 10 was sufficiently small not to produce much strain hardening, and the long period of the test neutralised most of the increase in strength which might have been expected. The alloy-cast steels tested previously in creep show but slight change in their tensile properties as a result of such treatment.

A temperature of 538 deg. C. is practically out of the strain-hardening range, and, therefore,

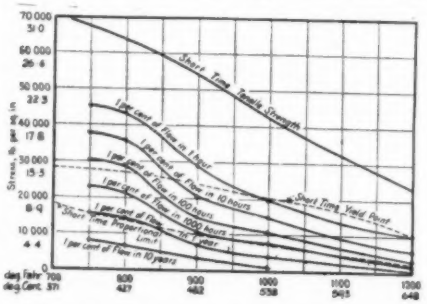


FIG. 18.—"ISO-FLOW-RATE" CURVES FOR CARBON CAST STEEL WITH SHORT-TIME TENSILE-STRENGTH, YIELD-POINT AND PROPORTIONAL-LIMIT CURVES DRAWN IN FOR COMPARISON.

there is no increase in the yield point, while elongation and reduction of area remain practically as formerly. Naturally, oxidation, pick-up of sulphur or other deteriorating elements, would alter results. The point is that, avoiding such chemical deterioration, no deterioration apparently occurs due to heat alone, or to the very slight stretching of the metal which occurred during the period of time which the creep test covered.

Engineering Application of Creep Data.

Curves taken from the A.S.T.M. 1928 Paper referred to above are included for information and for service to such engineers as may have occasion to use them. Fig. 17 is plotted logarithmically, stress in lbs. per sq. in. plotted against time in hours for 1 per cent. of flow, while Fig. 18 plots practically the same information as stress in lbs. per sq. in. against temperatures in zero degs. Fah. The former is interesting in that when the stress at which the tensile strength is reached in the short-time test is plotted against the time taken during the same short-time high-temperature test for the test-specimen on its way to destruction to stretch 1 per cent. (that is, approximately 3.6 secs., or 90 secs. for the full 25 per cent. elongation between yield point and ultimate strength), it falls upon extrapolation of the creep or long-time curve for that temperature. This seems to indicate that the well-known short-time test and long-time flow or creep test are relative to the applied stress.

From Fig. 18, a designer estimating equipment to operate at 480 deg. C. can determine at once that at 4.4 tons per sq. in. stress, the flow will not exceed 1 per cent. in 1,000 hrs., while at 1.7 tons per sq. in. it will not exceed 1 per cent. in 10 years. When oxidation, local overheating, etc., are avoided, creep of 1 per cent. in 10 years will do little harm other than cause distortion. There is little danger from sudden failure, since practically all ductile metals stretch at least 15 per cent. before final rupture. Of course, it is not intended by the engineer that the factor of safety shall be an irreducible minimum, but should such occur it will be indicated, without particularly serious consequence, by the distortion mentioned.

In Fig. 18 a short-time proportional limit has been sketched in. It will be remembered that in an early discussion concerning creep testing, French[5] suggested that a very accurately-taken proportional limit gives a fairly accurate indication of the stress permitting long life. It will be noted that up to the equi-cohesive temperature this appears to be approximately true, and indicates about 1 per cent. of flow in one year. However, at 455 deg. C. the 1 per cent. flow in one year falls below the proportional limit, while the curve for 1 per cent. of flow in 10 years is considerably below it all along its length.

There is another way of comparing the martensitic and austenitic steels in creep. This is shown in Table III. Here it is seen that, assuming a standard creep of 1 per cent. in 10,000 hrs., using in the first case 11.1 tons per sq. in. stress and in the second 0.44 ton per sq. in. stress, the assumed amount of creep will be obtained with martensitic steels shown at temperature 371 to 440 deg. C. with the high load, and with temperatures of 550 to 565 deg. C. with the lower load. With the austenitic steels, higher temperatures must be used to obtain the 1 per cent. of creep, namely, about 510 deg. C. with the 11.1 tons per sq. in., and as high as 871 deg. C. with the 0.44 ton per sq. in. stress. These two stresses, which perhaps are about the extremes at present used, present a fair comparison of possible applications of materials. The third column shows the range of temperature between these two assumed extremes of operating conditions. As was mentioned earlier, the non-ferrous metals are not applicable above comparatively low temperatures.

(To be concluded.)

A FURTHER STEP in the co-ordination of the activities of technical societies has recently been taken by the formation of the Association of Secretaries of Engineering Societies in Glasgow. The membership is representative of 17 associations, comprising the national societies and the Scottish branches of all the important British societies. One of the objects of the Association is so to arrange the dates of meetings of the constituent societies that there shall be the minimum of interference between the various fixtures. It is proposed to publish a joint programme of meetings, and to make reciprocal arrangements for attendance at meetings.

[5] "Methods of Test in Relation to Flow in Steels at Various Temperatures." H. J. French. "Proceedings, American Society Testing Materials," Vol. 26 (1926), Part II, page 7.

The Thermal Conductivity of Cast Iron Between 0 and 100 deg. C.*

By H. Thyssen, Jean R. Maréchal and Paul Lénaerts.†

[BELGIAN EXCHANGE PAPER.]

[The authors, after passing in review the theoretical principles of heat-transmission, describe a modified Despretz method of determining relative conductivities. A series of commercial cast irons were tested, using bars of increasing diameters, and the results obtained are set out in Table II and Figs. 3, 4 and 5. The main features are that conductivity is higher with an increasing phosphorus content and with diminishing diameters of bars. It is also postulated that the size of the graphite lamellæ is proportionate to the diameter of the bars. A commercial inference is drawn in connection with the phosphorus content of economiser castings, whilst pointers are given for the choice of cast iron of high conductivity for industrial applications.]

The various tables of physical constants furnish few figures relating to the thermal conductivity of cast iron. The figures given, moreover, are generally without any indication either of composition or structure, showing that the data in question are old and were obtained at a time when knowledge in regard to cast iron was imperfect.

At a time when cast iron is being used in the construction of so many apparatus (economisers for boilers, vats for the chemical industry, refrigerating plant, etc.), in which heat transmission plays an important part, it appeared very desirable to ascertain the factors which influence such conductivity in order to provide the makers with the necessary data for the production of castings which, while possessing good mechanical strength, will also show good thermal conductivity.

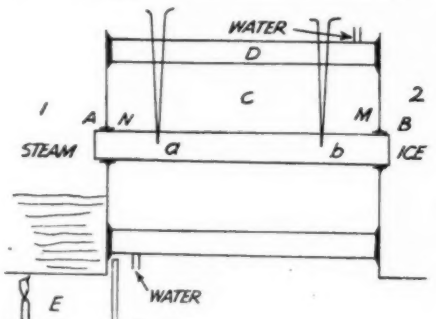


FIG. 1.—SHOWING THE METHOD USED FOR THE DETERMINATION OF RELATIVE CONDUCTIVITIES OF METALS.

Theoretical Principles.

A body immersed in a medium having a variable temperature has what are termed isothermal surfaces, *i.e.*, surfaces on which the temperature is the same at all points. At a given moment an equation may be formed for this surface in Cartesian co-ordinates as follows:

$$T(x, y, z, t) = \text{constant.}$$

In the simplest case, where these surfaces remain stationary, we obtain:

$$T(x, y, z) = \text{constant.}$$

In isothermal surfaces, if the normals are traced at any point we obtain lines of flow, and the volume limited by lines of flow resting on a closed surface is a tube of flow.

The fundamental hypothesis in the exchange of heat is as follows: the heat flows along the normal to the isotherms proportionally to the rate of diminution of the temperature along the normal, and proportionally to a coefficient which has always been regarded as being independent of the temperature. According to the very careful researches recently carried out by Forbes, however, it would appear that this coefficient is a function of the temperature.

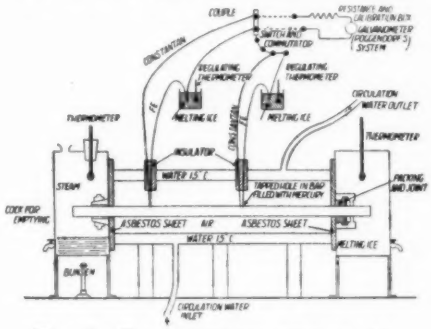


FIG. 2.—THE APPARATUS USED IN THE EXPERIMENTS.

This hypothesis may be converted into mathematical terms thus:

$$dQ = -k \frac{\delta T}{\delta \eta} dS$$ Q being the flow and k the conductivity.

If we term the velocity of flow U we obtain:

$$U = \frac{dQ}{dS} = -k \frac{\delta T}{\delta \eta}$$

The expression "velocity" may be used, as the heat behaves like a fluid.

If the components along the co-ordinate axes of the velocity U are termed u, v, w we obtain:

$$U = -k \frac{\delta T}{\delta x}$$

$$v = -k \frac{\delta T}{\delta y}$$

$$w = -k \frac{\delta T}{\delta z}$$

The heat entering an elementary volume dw during a given period in excess of the volume issuing from the same volume is:

$$\frac{\delta Q}{\delta t} dt = -\left(\frac{\delta u}{\delta x} + \frac{\delta v}{\delta y} + \frac{\delta w}{\delta z}\right) dw\ dt \quad \ldots (1)$$

A quantity of heat dQ which penetrates a volume filled with matter of ρ density, its specific heat being C, raises its temperature by a quantity δT, furnished by the equation:

$$\frac{\delta Q}{\delta t} dt = c\rho \frac{\delta T}{\delta t} dt\, dw \quad \ldots\ldots\ldots\ldots (2)$$

By comparing the equations (1) and (2) we obtain:

$$-\left(\frac{\delta u}{\delta x} + \frac{\delta v}{\delta y} + \frac{\delta w}{\delta z}\right) = c\rho \frac{\delta T}{\delta t} \quad \ldots\ldots (3)$$

or

$$+ k\left(\frac{\delta^2 T}{\delta x^2} + \frac{\delta^2 T}{\delta y^2} + \frac{\delta^2 T}{\delta z^2}\right) = c\rho \frac{\delta T}{\delta t},$$

which may be written: $k \Delta T = c\rho \frac{\delta T}{\delta t}$,

ΔT being the Laplacian coefficient of T,

by assuming that $\frac{k}{c\rho} = a^2$ we obtain

$$a^2 \Delta T = \frac{\delta T}{\delta t}.$$

For the stable condition this equation is reduced to: $\Delta T = 0$.

The special case in which we have to deal with an elongated cylindrical bar, the surface of which is not impermeable to heat, is now considered.

The equation $a^2 \frac{\delta^2 T}{\delta a^2} = \frac{\delta T}{\delta t}$ is not complete because in it no account is taken of lateral radiation.

If we take a bar of small section, in which the temperature may be regarded as uniform at every point in the same section, the isotherms are then straight sections.

According to Newton's law the heat lost by lateral radiation is proportionate to the peripheral surface and the difference in temperature between the bar and the surrounding medium.

Let two sections be taken x and $x + dx$ distant from the origin.

The quantity of heat entering is equal to:

$$k s \frac{\delta^2 T}{\delta x^2} dx$$

The quantity $c \rho s \frac{\delta T}{\delta t} dx$ heats the volume comprised between the two sections, and another quantity $p h T\, dx$ is lost by lateral radiation.

p is the perimeter of the base.

T is the excess of temperature between the bar and the surrounding medium.

h is the coefficient of lateral radiation.

We ought then to have

$$k s \frac{\delta^2 T}{\delta x^2} = c \rho s \frac{\delta T}{\delta t} + p h T.$$

This rather complicated equation can be simplified fairly quickly when we presume the stable condition to be attained.

During this period, in fact: $\frac{\delta T}{\delta t} = 0$.

We have $\frac{\delta^2 T}{\delta x^2} = \frac{ph}{sk} T = b^2 T$.

The general integral of this differential equation is:

$$T = Ae^{bx} + Be^{-bx}.$$

It is necessary to determine the integration constants. This can be done by considering the initial condition:

$T = To$ for $x = o$ $\quad To = A + B$

$T = T_1$ for $x = l$ $\quad T_1 = Ae^{bl} + Be^{-bl}$.

All the experiments carried out in this field have shown that A may be neglected as it is very small, the error being less than 0.5 per cent.

We therefore obtain:

$$T = To\, e^{-bx}.$$

It is on this theory that the method of Despretz for measuring relative conductivities is based.

Pieces of metal in cylindrical shape have one end immersed in an enclosure in which the temperature is constant, the other end being in the surrounding medium. The value of the coefficient h thus remains practically constant.

The space surrounding the bar is limited by a metal surface, which is maintained by means of a current of water at a constant temperature, say 15 deg. C. The experiment consists in taking the temperature at two points in the bar at a known distance: x and x'. If θ and θ' represent the temperatures at these two points:

$$\theta = To\, e^{-bx}$$

$$\theta' = To\, e^{-bx'}$$

$$\frac{\theta}{\theta'} = e^b (x' - x).$$

This equation gives b and consequently the ratio $\frac{h}{k}$. The conductivities are in inverse ratio to the parameters b^2 determined by the experiment.

As the method gives only the value of b, *i.e.*, the ratio $\sqrt{\frac{h}{k}}$ it is necessary to obtain an element for comparison. What one requires to know is

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* Paper presented at the Twenty-Eighth Annual Convention of the Institute of British Foundrymen at Birmingham yesterday.

† The authors are respectively the Professor and Lecturers in the Department of Metallurgy at the University of Liége.

the value of k. By operating first on a bar of pure electrolytic copper identical as regards geometrical dimensions, surfaces, etc., with the cast-iron bars experimented upon, one eliminates the factor k and obtains a number which represents the relative conductivity of the cast iron as compared with the electrolytic copper taken as a standard, when by deduction the conductivity of the different metals can be compared.

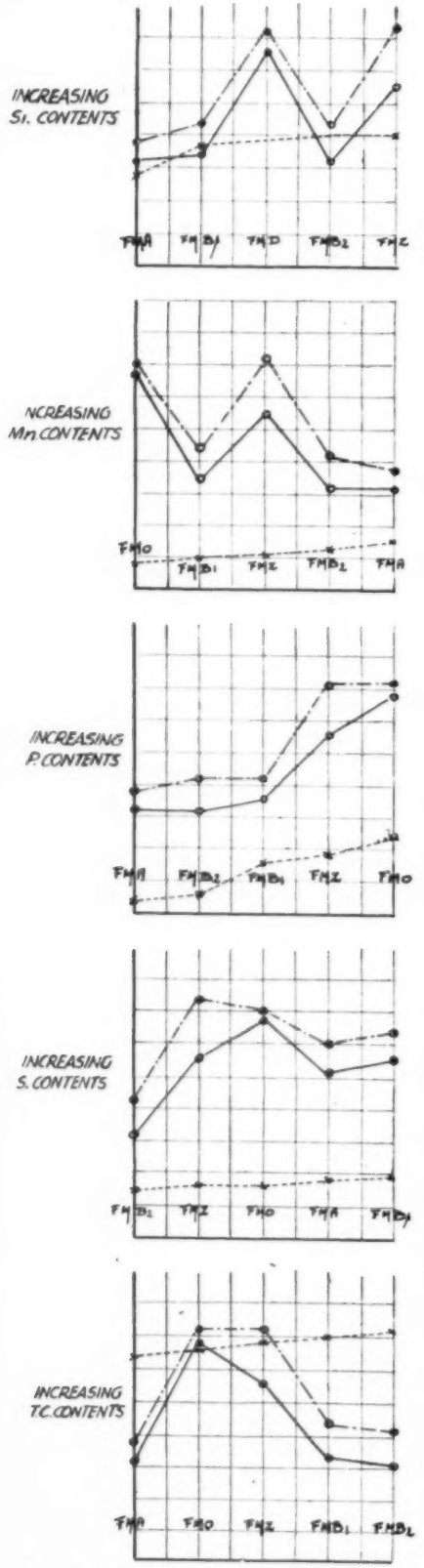


Fig. 3.— Heat Conductivities of Various Commercial Irons.

The full lines refer to bars of 80 mm. dia.; broken lines to 30 mm., and the dotted lines to the variation of the element in question. In ordinates 1 mm. = 0.01% of conductivity; 1 mm. = 0.1% Si, Mn, P and C; and 1 mm. = 0.01% S.

Experimental Method.

The method of Despretz was in so far modified that in all the experiments the two ends of the bar were maintained at rigorously fixed temperatures of 100 deg. C. and 0 deg. C. (steam at atmospheric pressure and melting ice). Thermometers regulating to $\frac{1}{10}$ of a degree were used. The temperature at two points 25 cm. apart was measured by double thermo-electric couples of iron-constantan previously calibrated with the same galvanometer, the same resistance box, the same distance for the reading scale, the same length of wires, etc.

The temperatures at the two points in the bar were obtained by taking as a basis the diagrams traced between 0 and 100 with the deviations in abscissæ and the corresponding temperatures in ordinates. Apart from errors of calibration these curves were practically straight lines. (The double couples are used in order to eliminate the contact e.m.f. One of the welds was immersed in melting ice maintained at the true constant temperature of 0 deg. C. by the addition of pounded ice and regulated by thermometer to $\frac{1}{10}$ of a degree.)

All the bars were 60 cm. long and 3 cm. in dia. The end A was immersed in steam and the other end B in pounded ice, lightly sprinkled with water from the melted ice. At A and B there were tapered joints to prevent the return of any steam or water into the enclosure C. The joints were kept in position by nuts placed at A and B.

In the cylinder D, the water was kept circulating at 15 deg. C., so that in all the measurements the coefficient of lateral radiation should be the same. The cylinder D was insulated from the containers A and B with asbestos. Similarly, any transmission of heat between the Bunsen jet E and the cylinder D was prevented by means of an asbestos casing.

An important point in the experiment was to maintain the same length for each bar, after the apparatus was dismantled, between the compartments I and II, and to ensure that the length of the submerged parts A and B, either in the steam or in the melting ice, should remain the same. For this purpose a distance piece was used to keep their distances uniform.

The measuring couples were enclosed in an insulating sheath, where they passed through the circulation cylinder D. To prevent variations in specific conductivity with the temperatures a 1,000-ohm resistance was inserted in the circuit of the galvanometer, as the latter when calibrated showed a sensitiveness of $3.2 \cdot 10^{-9}$ A, the scale being placed at a distance of 2.8 metres (Poggendorf's method). Thus the fluctuations of temperature at certain points of the circuit had no influence on the e.m.f. which produced the temperatures, as had been expected.

To measure the fall in temperature along the axis, holes 2 mm. in dia. and 15 mm. in depth were bored in the bars. They were filled with mercury, into which the extremity of the couple was inserted. Thus a perfect contact was obtained, and the three-way reversible switch enabled the temperature of the two couples to be taken alternately (see Fig. 2).

Test-Bars.

It was found impossible to obtain cast iron containing one chemical element, the variation of which was continuous while the others remained constant. It was necessary to work with the types of iron generally used in the foundries of the Compagnies des Conduites d'Eau. Their composition, transverse strength and tensile strength are given herewith.

As it was desired to ascertain from the tests not only the influence of the chemical elements but also that of the structure, five bars 60 cm. in length and 30, 40, 50, 60 and 70 mm. in diameter respectively were cast in each of these metals for the purpose of varying the structure by variation of the law of cooling. All the bars were then turned to the diameter of 30 mm.

Results of the Tests.

These bars, on being subjected to the tests in the apparatus by the method described, gave the results shown in Table II. The figures express the relative conductivities in relation to a bar of electrolytic copper of the same section and length.

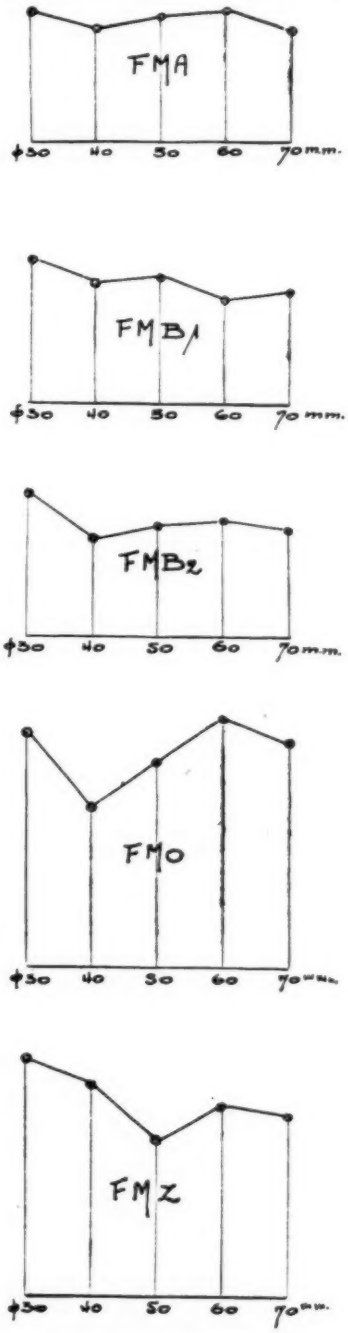


Fig. 4.—Conductivity with Increasing Diameter.

Generally speaking, and without knowing the result of the micrographical analysis, one conclusion may be drawn from the following diagrams, viz., that the conductivity improves as

the percentage of phosphorus increases. Fig. 3 shows the results graphically.

The various metals classified in the order of the increasing contents of each of the elements in their composition are shown by abscissæ, the relative conductivities of the bars of the smallest and largest diameter being shown by ordinates. The first points are connected by dotted lines, the second by solid lines. The curves of relative conductivity of the bars of the other diameters fall nearly between these two external curves.

The contents in each of the elements under consideration are also plotted as ordinates. As has been already mentioned, an increasing conductivity will be noted in relation to the phosphorus contents. At first sight it is not possible to deduce any law relating the influence of the other elements.

To observe the influence of the structure of the metals the lamellæ of graphite present in a determined area were numbered. For this purpose zones of the different metals were projected with the same enlargement on to the ground glass of a Le Chatelier metallographic apparatus. Two perpendicular diameters were traced and the number of flakes of graphite intersected by them was counted.

The following table gives the average of the two figures obtained for each diameter; these numbers may be regarded as being in inverse ratio to the size of the graphite lamellæ:

It will be seen from these figures that the size of the lamellæ is certainly in proportion to the diameter of the bars. It is clear that the larger the bar is, the slower will be its rate of cooling after casting and the larger will be the lamellæ of graphite.

It may also be noted that according to Figs. 3 and 4 and Tables II and III that the figures of conductivity are higher for the smaller diameters (apart from a few local exceptions probably caused by other factors). This is particularly clear in the case of the metals F.M.B.1, F.M.B.2 and F.M.Z. (Fig. 4). In F.M.O. the high phosphorus content conceals all the other influences and gives a higher conductivity.

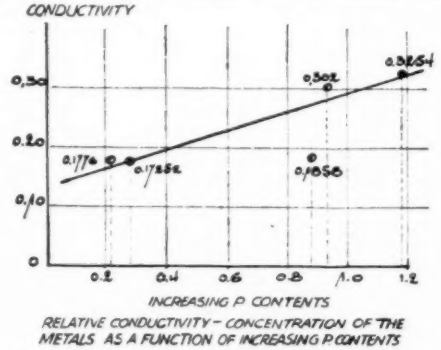


FIG. 5.—SHOWING THE INFLUENCE OF PHOSPHORUS ON HEAT CONDUCTIVITY.

From all this it may be concluded that crystallisation in fine lamellæ is favourable to the conduction of heat, but that this influence may be concealed, when the phosphorus content exceeds a certain limit, by an encroachment of the phosphorus eutectic, which is probably a better conductor of heat than iron and its solid solutions.

If one plots the phosphorus content of the various metals subjected to the tests as abscissæ, and the relative conductivities—the averages of the various metals of the same composition (6th column of Table II)—as ordinates, one obtains the points 1, 2, 3, 4 and 5 in Fig. 5. These points are fairly in line with the solid straight line drawn. The dispersion may be due to the difference in structure of the metals and to variation in the chemical composition of the other elements, principally of the total carbon, which fluctuates between 3.61 and 3.21 per cent., and, as has been pointed out, influences the quantity of phosphorus dissolved.

The conductivity would therefore appear to be practically proportionate to the percentage of phosphorus, or, rather, of phosphorus eutectic present in the metal. This qualification shows that caution must be observed, and that the curve must not be extrapolated beyond the limits.

TABLE I.—*Composition of Metal Used.*

	T.C.	Si.	Mn.	P.	S.	Transverse strength. Tons per sq. in.	Tensile strength. Tons per sq. in.
F.M.O.	3.27	1.84	0.426	1.18	0.085	26.6	12.7
F.M.A.	3.21	1.31	0.776	0.22	0.088	33.6	17.6
F.M.B.1	3.49	1.82	0.500	0.88	0.095	25.4	13.3
F.M.B.2	3.61	1.96	0.639	0.28	0.066	21.8	10.1
F.M.Z.	3.48	2.01	0.532	0.93	0.080	22.2	10.8

TABLE II.—*Relative Conductivities of the Irons Shown in Table I at Increasing Diameters.*

Diameter in mm.	30	40	50	60	70	Averages.
F.M.A.	0.1908	0.1656	0.1835	0.195	0.1632	0.1776
F.M.B.1.	0.22	0.182	0.195	0.160	0.172	0.1858
F.M.B.2	0.215	0.144	0.1675	0.1761	0.160	0.17252
F.M.O.	0.357	0.245	0.310	0.375	0.340	0.3254
F.M.Z.	0.365	0.325	0.245	0.295	0.280	0.302

While not being complete (for the influence of the metallic matrix has not yet been considered), this Paper, by throwing light on the influence of two important factors, furnishes certain practical data for the production of castings in which good conductivity is required. At present a very low phosphorus content is too frequently insisted upon—in economiser castings, for example. This would seem to be wrong, particularly as a rather high phosphorus content has no very detrimental effect on the mechanical properties, and does not seem—from the slight experience the authors have had of the phenomenon—a cause of destruction from "ageing."

The authors had had an opportunity of examining a cast-iron economiser, in which the composition of the metal was as follows: T.C. 3.22, Si 2.31, Mn 0.47, S 0.057 and P 1.4 per cent. It has been in use since 1923, a period of seven years, and was still in good condition.

TABLE III.—*Graphite Flakes and Diameter.*

Diameter in mm.	F.M.A.	F.M.B.1.	F.M.B.2.	F.M.O.	F.M.Z.	Averages.
30	15	8.5	8	9.5	12.5	10.7
40	8	6.5	8.5	10.5	10.5	8.8
50	8	6	7	9	7	7.4
60	5	6	10	10	6	7.4
70	7	8	10	7	3	7

THE TATA IRON & STEEL COMPANY have secured a contract with Italian consumers to supply 15,000 tons of high-silicon pig-iron from their Jamshedpur works on very moderate terms.

Making a Condenser Shell.*

BY L. FODEN.

Suitable building tackle is first assembled. The bottom plate is set down on packings in a pit which has a centre plugged to the floor. This plate is set centrally with the spindle centre, and then a coping or bottom ring is set upon it. A line is then chalked on the inside of the ring on the bottom plate, thus giving the size and shape of the ring. A seating is built on the bottom plate, keeping ½ to 1 in. clear of the chalk line. After this, the seating is marked on all four centres, and additionally where the branch fits. A dummy board is then set to the size of the coping required. The bottom of this board is required to ride on the seating to give the height of the job. When this is completed, a 4½-in. wall is built all round, having ⅜ in. of space between the board and bricks. This ¾-in. space is to allow for the roughing up with loam to bring the job to size. Black loam is utilised. When the top of this dummy board is approached, a plate is put on, being about an inch clear of the board. This is done as a binder or holder for the wall, which is beneath it. The condenser may have a neck or heading which is out of centre and smaller in size, and so on this plate two rails can be set and another centre set up for building the neck or heading, being either 9 in. or 10½ in., or whatever is required, out of centre with the body of the condenser. After the dummy is built, it is treated on the surface with water or thin blacking, and parting sand is dusted on, so that, when the dummy is taken down, it parts away from the coping easily. A fresh start is then made at the bottom of the job, which, of course, is the seating. The coping ring is bedded down on the loam, this being sprinkled with parting sand, so that it will not lift the loam when parting the coping from the bottom plate.

The ring is built up, first of all setting the in-gates for casting, and also the down-gates. In this manner, each ring is built up until they reach the top of the branch, over which is set or bedded what is known as a main grid, this being used to carry the top of the branch, the ends and back of the branch bearing on the building ring, and bolts carried upwards until the top ring is reached. Two rails are placed crosswise on the ring to carry the grid by bolting, and to bear the weight of the brickwork.

When the coping is complete, round the outside of the coping where the bottom or coping ring and the bottom plate are, marks are made on all four sides. Then the coping is lifted away for finishing, leaving the bottom plate and seating in position. On the seating, a core is then struck up, being smaller than the coping by the thickness of metal. This is a strong wall, being 18 in. or 2 ft. wide at the branch side and 12 to 14 in. at the body or wedge side.

The core finished, the branch is then built to it, and, when all is complete, the core and the coping are stoved. After drying, the core is set in a pit suitable to bind down the job for casting. The coping is then lowered on to logs while two or three cores are bolted in it. After this the coping is centred over the core and lowered down on to its bed on the bottom plate. Then the top plates are lowered on, and the job is prepared for casting.

* A Paper read before the Lancashire Junior Section of the Institute of British Foundrymen, Mr. H. V. Grundy presiding.

Trade Talk.

THE KETTON PORTLAND CEMENT COMPANY, LIMITED, is issuing at par 150,000 6 per cent. cumulative first preference shares of £1 each.

GWYNNES PUMPS, LIMITED, Lincoln, have secured the contract for the pumping machinery for the dry dock which the Southern Railway Company is building at Southampton.

THE WALLSEND SLIPWAY & ENGINEERING COMPANY, LIMITED, Wallsend-on-Tyne, have secured the contract to supply the oil-burning installation for the new Cunarder being built on the Clyde.

MESSRS. SWAN, HUNTER & WIGHAM RICHARDSON, LIMITED, of Wallsend, launched last week the motor tanker "Carditor," of 11,500 tons deadweight, for the Anglo-Saxon Petroleum Company, Limited.

THE OUTPUT of the Belfast shipyards for the first five months of the year is three vessels of an aggregate tonnage of 31,000. This compares with 12 vessels of 80,000 tons in the same period last year.

THE LANCASHIRE FOUNDRY COKE COMPANY, LIMITED, Altham, Accrington, have opened London offices at 20, Budge Row, E.C.4, under the management of Mr. A. C. Mann, late of the Lowmoor Coke Company, Limited.

CLYDE SHIPYARDS launched during May six vessels totalling 31,500 tons, bringing the tonnage for the first five months of the year up to 93,271, represented by 34 vessels. The total output for all the Scottish shipyards last month was 32,500 tons.

THE ORDER Messrs. Marshall, Sons & Company, Limited, Gainsborough, have received from Russia is for 175 portable locomobiles for the timber industry. The value of the contract is nearly £100,000. Extended credit terms of payment have been arranged.

GENERAL REFRACTORIES, LIMITED, Wicker Arches, Sheffield, have received an important export order for refractory materials, the execution of which will fully occupy the company's firebrick works and necessitate the reopening of another brickworks which had been closed down.

WITH THE PASSING of the Bill enabling the Government of the Union of South Africa to acquire the "B" shares of the South African Iron & Steel Industrial Corporation, Limited, it is expected that £1,000,000 will be spent this year on the Pretoria works. The foundations are now being laid, and a branch railway which is being built will tap the Rustenburg iron-ore deposits.

THE FIRST SECTION of the floating dock constructed by Messrs. Swan, Hunter & Wigham Richardson, Limited, Wallsend, for the Wellington Harbour Board, New Zealand, was launched on May 30, the second section on June 1, and the third section on June 3. The dock has a lifting capacity of 17,000 tons. The three sections will be joined up and towed out to New Zealand.

IN ACCORDANCE with the intimation in the annual report, the directors of the British Aluminium Company, Limited, announce that all the outstanding 5 per cent. prior lien debentures will be redeemed on June 30 at £105, plus accrued interest. The amount outstanding of the original issue of £1,000,000 is £745,600. In December last an issue of £2,500,000 5 per cent. first mortgage debenture stock was made.

THE NATIONAL UNION OF FOUNDRY WORKERS convened a conference in Sheffield last Saturday of officials of Trade Unions who are negotiating with the Engineering Trades Employers' Federation in regard to working conditions. It was decided to form a "committee of action" and to communicate with those Unions not represented, inviting them to appoint a representative on this committee. A mass meeting is to be held next Saturday, at 2.30 p.m., at the Foundry Workers' Club and Institute, Birch Road, Sheffield, of shop stewards and representatives in engineering firms where there are no stewards.

THE CENTRAL BOARD of the Shipbuilding Employers' Federation, at a meeting at Carlisle on Friday, May 29, had under consideration the cost of steel shipbuilding material when obtained from British steel makers. For several years practically all the British shipbuilding firms have been parties to a scheme by which, in return for an undertaking to purchase exclusively from British makers, a price rebate has been obtained. It was pointed out that at the time this arrangement was entered into there was less difference between the prices of British and foreign steel than there is now, and the Central Board resolved to renew their efforts and representations to the British steel makers, pointing out the necessity for an early reduction of steel prices.

THE BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION'S new headquarters in Euston Street, London, N.W.1, were opened by Lord Rutherford on Monday, June 8, on the occasion of the Association's tenth annual meeting. Research work hitherto conducted at the Sheffield and Birmingham Universities will now be carried out in the Association's own laboratories, which are equipped with two electric annealing furnaces, electric crucible furnaces, tensile-testing machines, a microscope room, and apparatus for the measurement of the atmospheric corrosion of metals, in connection with which a flat roof will be utilised for exposure tests. Among those attending the proceedings were Sir Josiah C. Stamp, Sir William Larke, Prof. C. H. Desch and Mr. W. J. Dawson.

REPORTS ARE CURRENT at Sydney, Nova Scotia, that Mr. H. G. Kelly, general manager of the Dominion Steel & Coal Corporation, Limited, who recently returned to Canada from Great Britain, is likely to announce important decisions in connection with the investment of new capital in the Nova Scotia coal and steel industries. One statement is to the effect that $10,000,000 are to be spent on additions to the Sydney steel plant, but no confirmation can be secured from the local officials. It is, however, regarded as practically certain that the Corporation will proceed with the erection of three 100-ton open-hearth furnaces, displacing six older furnaces and greatly increasing the output capacity. The Dominion Steel & Coal Corporation, according to statements made at the recent annual meeting of the shareholders, is operating this year on a basis of activity 20 per cent. less than was experienced last year for the same period. The tonnage of iron and steel disposed of in 1930 was about 77½ per cent. of the tonnage sold in the previous year.

Personal.

SIR GEORGE HUNTER, the Tyneside shipbuilder, returned to London on June 2 from his thirty-second visit to the United States.

SIR WILLIAM HENRY BRAGG has been awarded the Order of Merit in recognition of his eminent services in the advancement of science. Sir William is famous for his work on X-rays and crystals, for which, in conjunction with his son, Prof. W. L. Bragg, he received the Nobel Prize in 1915. He has been Director of the Davy-Faraday Research Laboratory since 1923.

MR. JOHN S. BOYD has been appointed permanent Vice-President of the Shipbuilding Employers' Federation. The office of permanent Vice-President, which has thus been revived, was formerly held by Sir Andrew Duncan, until he left the industry to become chairman of the Central Electricity Board in the early part of 1927. Mr. Boyd has been secretary of the Federation since that time. Mr. Alexander Belch, who has been associated with the Federation for 20 years and has recently been deputy secretary, has been appointed secretary.

DR. CECIL H. DESCH, Professor of Metallurgy at Sheffield University, has been appointed superintendent of the Metallurgical Department of the National Physical Laboratory, in succession to Dr. W. Rosenhain. Dr. Desch will not take up the new appointment until 1932, as he had previously accepted an invitation from Cornell University, New York, to give a course of lectures there during the winter session 1931-32. While in Sheffield, Prof. Desch has done much to advance the work of the Applied Science Department. He began studying metallurgy as assistant to the late Prof. Huntington. In 1909 he was appointed lecturer in metallurgy at Glasgow University, and became professor of this subject at the Royal Technical College, Glasgow, in 1918. He went to Sheffield in 1920 as Professor of Metallurgy and Dean of the Faculty of Metallurgy. He is a Past-President of the Faraday Society, of the Chemical Section of the British Association, and of the Sheffield Society of Engineers and Metallurgists. He was elected Fellow of the Royal Society in 1923.

Contracts Open.

Wilton, June 19.—740 yds. of 4-in. cast-iron gas main, for the Town Council. The Gas Manager, 7, North Street, Wilton.

Wokingham, June 24.—23 miles of cast-iron water mains, for the Rural District Council. Mr. J. S. Alford, 11, Victoria Street, Westminster. (Fee £5, returnable.)

Reports and Dividends.

Barrow Hematite Steel Company, Limited.—Profit of £6,341, reducing the debit balance brought forward to £32,460.

Callender's Cable & Construction Company, Limited.—Final dividend of 10 per cent., making 15 per cent. for 1930.

Falkirk Iron Company, Limited.—Profit, £6,908; brought in, £46,902; dividend absorbs £12,563; carried forward, £41,247.

Pressed Steel Company of Great Britain, Limited.—Net profit, £39,441, which increases the amount to be carried forward to £75,117.

Stanton Ironworks Company, Limited.—Final dividend of 6 per cent., tax free, on the ordinary shares, making 10 per cent., tax free, for the year ended March 31.

Whessoe Foundry & Engineering Company, Limited.—Profit, after providing for taxation, £27,065; brought in, £6,594; depreciation, £5,425; directors' remuneration, £2,452; staff welfare schemes, £1,246; dividend of 10 per cent.; carried forward, £9,035.

Patent Specifications Accepted.

The following list of Patent Specifications accepted has been taken from the "Illustrated Official Journal (Patents)." Printed copies of the full Specifications are obtainable from the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each. The last numbers given are those under which the Specifications will be printed and abridged, and all subsequent proceedings will be taken.

16,211. KRUPP GRUSONWERK AKT.-GES., F. Metal-extrusion presses for the production of rod-like or tubular-shaped bodies. 342,984.

5,596. DENNISON, W. E. Iron alloys. 343,745.

977. SUTTON, H., and COCKS, H. C. Electro-depositing on aluminium and aluminium alloys. 343,685.

1,290. PIGGOTT & COMPANY, LIMITED, T., and BARKER, T. P. Manufacture of pressed-steel tanks. 343,690.

38,398. BORNAND, E., and SCHLAEPFER, H. A. Casting of metal. 343,648.

38,825. POSSENTI, A., and SCORZA, C. Method of and apparatus for removing from sand moulds castings having the shape of a solid of revolution. 343,652.

117. DENNISON, E. Cleaning of metal bars. 343,672.

34,956. BAUMANN, K., and TURKUS, G. Water-tube boilers. 343,484.

35,170. KRUPP AKT.-GES., F. Steel alloys. 343,464.

35,231. DAVIES, S. Machines for dusting and polishing tinplates and the like. 343,470.

35,245. HANNOVERSCHE MASCHINENBAU AKT.-GES. VORM. G. EGESTORFF (HANOMAG) and BARSKE, U. Water-tube boilers, more particularly boilers for railway and portable steam engines. 343,491.

34,539. SPENCER, A. L. HITCHCOCK. Vertical boilers. 343,438.

34,808. OESTERREICHISCHE SCHMIDT-STAHLWERKE AKT.-GES. Cobalt high-speed tool steel. 343,508.

24,116. MULTHAUPT, P. Forging or extruding of liquid or plastic iron, steel and other metals or alloys. 343,002.

27,069. SKODA WORKS, PLZEN. Acid-proof alloys. 343,003.

27,568. SMALLWOOD, A. Clamp or retaining device for structural tubes, bars and the like. 343,106.

33,657. MATHESIUS, W., and MATHESIUS, H. Obtaining ferro-titanium alloys. 343,007.

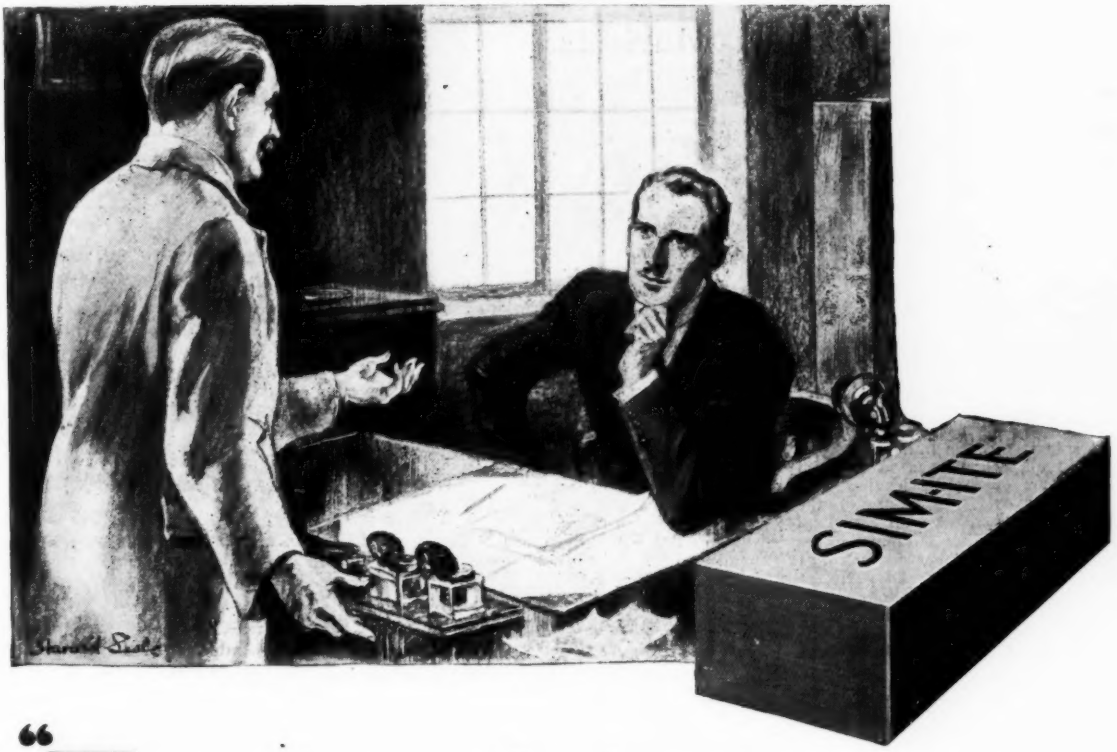
34,974. HETZEL, A. R., and HETZEL, J. M. (trading as Vereinigte Silber-Hammerwerke Hetzel & Company). Combining aluminium or aluminium alloys with other metals or alloys by welding. 343,156.

35,751. SMALLWOOD, A., and FALLON, J. Furnaces and/or apparatus for the annealing or heat-treatment of metal and other goods. 343,187.

38,080. KIRKE, P. St. G. Fire-tube boilers and water-heaters. 343,234.

599. AKT.-GES. BROWN, BOVERI, ET CIE. Arrangement for annealing metal articles. 343,262.

1,931. BABCOCK & WILCOX, LIMITED (Babcock & Wilcox & Company). Return bends for tubes and method of forming the same. 343,279.



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GIBBONS' REFRACTORIES

GIBBONS (DUDLEY) LIMITED, ***Head Office:*** **Dibdale Works, Dudley, Worcs.**

Phone: Dudley 3141. *Telegrams: "Machine, Lower-Gornal."*

London Office: **151, Palace Chambers, S.W.1.** *'Phone: Victoria 0128.*

(Adjacent Westminster Tube Station)

Streets

Iron and Steel Markets.

Pig-Iron.

MIDDLESBROUGH.—Business is scarce in the pig-iron market. The demand is poor, consumers being reluctant to buy at the fixed Cleveland quotations. Notwithstanding the assurances to the contrary of the makers, the consumers are hoping that prices will fall. The low prices of Cleveland iron delivered in Scotland have resulted in a few small orders being placed, although it is declared that makers will lose money on these contracts. These preferential terms to Scottish consumers cause a certain amount of resentment locally, and have in some cases resulted in pig-iron supplies being drawn from abroad. On the other hand, Cleveland cannot afford to lose entirely its Scottish trade, and but for price-cutting Cleveland iron would be shut out of Scotland entirely. Stocks have been inclined to increase lately, but a blast furnace producing Cleveland iron at South Bank which was in need of repair has been put out of action, leaving only 22 furnaces in operation over the whole of the North-East Coast, of which seven are on Cleveland iron and seven on hematite. Fixed minimum prices for Cleveland iron, f.o.t. or f.o.b., are:—No. 1 foundry, 61s.: No. 3 G.M.B., 58s. 6d.; No. 4 foundry, 57s. 6d.; No. 4 forge, 57s. per ton.

Conditions are little altered on the hematite market. The restarting of the Ayresome Ironworks tends to throw more hematite on the market, although the bulk of the output of the extra furnaces has been sold for two or three months ahead. Prices have been depressed further, and some of the makers have now a rather pessimistic outlook. Most sales are now made direct from the works to the consumer, and merchants are not allowed to undersell producers in the home market. Nevertheless, price levels have a downward tendency, and a cut of 1s. per ton brings the quoted figure for East Coast mixed numbers down to 64s. per ton. Large orders could be placed on still more favourable terms. No. 1 quality is at a premium of 6d. per ton. Bessemer mixed numbers on the North-West Coast are quoted at 66s. per ton at works.

LANCASHIRE.—Although it is questionable if there has been much change for the better in the general situation, reports tend to show that the order-books of one or two Lancashire foundries are better than they have been for a month or two. For delivery to consumers in the Manchester zone, Derbyshire and Staffordshire descriptions are quoted at 67s. per ton, with North-East Coast iron also at 67s. The price of Northamptonshire foundry is 65s. 6d. and Derbyshire forge 62s. Scottish foundry brands are at about 88s., with West Coast hematite iron at 80s. 6d.

MIDLANDS.—Even at the present reduced rates, ironfounders are in no hurry to enter into forward buying, contenting themselves with ordering supplies for their immediate needs. For delivery to Birmingham and Black Country stations the furnaces still quote 62s. 6d. for Northants No. 3 and 66s. for Derbyshire, North Staffordshire and Lincolnshire No. 3.

SCOTLAND.—A reduction of 2s. 6d. per ton in Scottish foundry iron, making the basis price 71s. f.o.t. furnaces for No. 3 foundry, has been intimated by the Scottish Ironmasters' Association, together with a reduction of 2s. per ton in the price of Scottish hematite mixed numbers to 70s. f.o.t. steelworks. No noticeable improvement in trade has resulted from this overdue reduction, which even now leaves foundry iron dearer instead of cheaper than hematite. While the Scottish pig-iron makers are quoting as a fixed minimum price 71s. per ton for No. 3 foundry, f.o.t. furnaces, with a minimum of 2s. 6d. per ton extra for No. 1, the price of Continental No. 3 is 52s., f.o.t. Grangemouth. Middlesbrough No. 3 is at 59s. 6d.

Finished Iron.

Business in this market is very dull. Orders are scarce, the lack of specifications for crown and nut and bolt iron being particularly noticeable. Even in the market for marked bars, where foreign competition is not encountered, conditions are quiet, although the price of £12 is maintained. Crown iron is offered in Staffordshire at prices between £9 5s. and £10 per ton. A really good brand of crown iron is available at £9 15s. Nut and bolt bars are at about £8 12s. 6d. per ton, but little support is forthcoming for this grade, owing to the encroachment of Belgian material. The foreign No. 3 product is obtainable at the delivered price of £4 15s.

Steel.

The position at the finished-steel works is far from good. All the works are short of orders, operations being almost entirely dependent on small orders, making economic working impossible. The shipbuilders have few specifications to give out, and are agitating for lower prices, threatening to turn over to foreign steel unless these are forthcoming. There is a poor demand for steel bars and sheets. Prices of Continental semi-finished steel are still falling. Sheet bars f.o.b. Antwerp are now at a maximum of 64s. for ordinary specifications. In some directions 63s., with 62s. for heavy weights, is reported to have been taken. These figures, if not taken by all the works, have been accepted by some producers, among them French works. Continental billets are now at 63s. for 2 in., and 62s. for 2½ in. to 4 in. A large parcel of 2-in. billets has been sold at a price below 63s.

Scrap.

The Cleveland scrap iron and steel market has been rather more active in the past week. A few outlets for the accumulated stocks have been found by drastic price-cutting. Ordinary-quality cast-iron scrap is now at 44s., with good machinery quality down to 45s. 6d. In the Midlands stocks are increasing, while the demand is steadily falling-off. Good heavy machinery cast-iron scrap in cupola sizes is offered at 47s. 6d. to 50s., with light cast iron at 37s. 6d. In Scotland the position is also bad. Few orders are forthcoming. First-class machinery metal, in pieces not exceeding 1 cwt., is quoted at 50s., while ordinary cast-iron scrap to the same specification is at 45s. to 46s. The above prices are all delivered consumers' works.

Metals.

Copper.—A rather better feeling has prevailed in this market during the past week. The rally on Wall Street led to a certain amount of "bear" covering, the disappearance of the cheap parcels of refined metal, and some fairly good buying by consumers both in the United States and on the Continent. Nothing definite has been revealed yet concerning the recent New York conference of copper interests, and no more is known regarding the plans for the further curtailment of output which were believed to have been under consideration.

Closing quotations:—

Cash.—Thursday, £34 to £34 2s. 6d.; Friday, £35 7s. 6d. to £35 10s.; Monday, £34 10s. to £34 11s. 3d.; Tuesday, £35 3s. 9d. to £35 6s. 3d.; Wednesday, £35 3s. 9d. to £35 5s.

Three Months.—Thursday, £34 12s. 6d. to £34 15s.; Friday, £36 to £36 2s. 6d.; Monday, £35 5s. to £35 6s. 3d.; Tuesday, £35 18s. 9d. to £36 6s. 3d.; Wednesday, £35 17s. 6d. to £35 18s. 9d.

Tin.—Movements on this market are uncertain. Consumption generally remains disappointing, and sentiment at present is subdued by the large surplus of metal now existing. A supporting influence is the rumour that an international syndicate or pool has been definitely formed to carry part of the stocks. When this rumour is substantiated there will probably be a very sharp change round in sentiment. As for prices, the market is meeting with considerable resistance at the present level, and, until the general situation improves as the result of restriction or a change for the better in consumption, it is not impossible that prices may hold.

Official closing prices:—

Cash.—Thursday, £100 5s. to £100 7s. 6d.; Friday, £100 10s. to £100 12s. 6d.; Monday, £100 12s. 6d. to £100 15s.; Tuesday, £100 15s. to £100 17s. 6d.; Wednesday, £103 2s. 6d. to £103 5s.

Three Months.—Thursday, £102 to £102 2s. 6d.; Friday, £102 2s. 6d. to £102 5s.; Monday, £102 2s. 6d. to £102 5s.; Tuesday, £102 7s. 6d. to £102 10s.; Wednesday, £104 12s. 6d. to £104 15s.

Spelter.—A little more interest on the part of users has been noticed and the market has had a better tone. It cannot be said that any considerable increase has taken place in the number of orders passing, but the undertone of the market at its present level appears to be quite firm.

Daily fluctuations:—

Ordinary.—Thursday, £9 13s. 9d.; Friday, £9 18s. 9d.; Monday, £10; Tuesday, £10 5s.; Wednesday, £10 17s. 6d.

Lead.—The slightly better tone of the market last week was not due to any fundamental improvement, but rather to the fact that the price is at such a low level that it responds to any change in sentiment. The better tone in other markets also had a stimulating effect on lead.

The week's prices have been:—

Soft Foreign (Prompt).—Thursday, £10 7s. 6d.; Friday, £10 16s. 3d.; Monday, £10 12s. 6d.; Tuesday, £10 17s. 6d.; Wednesday, £11 6s. 3d.

The Association of Secretaries of Engineeering Societies.

The formation of the Association of Secretaries of Engineering Societies, in Glasgow and the West of Scotland, represents another move in the direction of the co-ordination of the activities of technical societies. The Association will be able to arrange the meetings of its constituent societies, so that there will be the minimum of interference between the various fixtures. Seventeen associations, including the Scottish Branch of the Institute of British Foundrymen, are represented in the membership. The convener of the Association is Mr. P. W. Thomas, secretary of the Institution of Engineers and Shipbuilders in Scotland.

Catalogue Received.

Welding Equipment.—A four-page leaflet, sent to us by the Metropolitan-Vickers Electric Company, Limited, of Trafford Park, Manchester, deals with a new line of automatic welder. Most of the reading matter is related to some form of tank welding, but page 4 describes and illustrates a handy equipment useful in the fettling shops of large steel foundries. The machine enables hand welding to be carried on without having the disadvantages of having to renew the electrode periodically. The equipment includes a drum of electrode wire, which is fed by means of rollers through a length of hollow steel-cored flexible copper conductor, attached to the end of which is an electrode guide.

Thermal Expansion of the Alloys of Iron, Nickel and Cobalt.—The following is the synopsis of this Paper by Mr. Hakar Masumoto:—The mean coefficient of the thermal expansion between 30 deg. and 100 deg. binary and ternary alloys of three ferro-magnetic substances, iron, nickel and cobalt, has been measured, and the relation between this coefficient and the equilibrium diagrams of these systems has been studied. Generally, the hexagonal solid solution has a greater, and the alpha solid solution a smaller coefficient of expansion than the gamma solid solution. Both the minimum at 18 per cent. and the maximum at 25 per cent. of nickel content found in the expansion coefficient concentration curve of iron-nickel alloys becomes rapidly inconspicuous on the addition to them of cobalt. At the same time, the small coefficient of expansion of "Invar" rapidly diminishes, reaches a minimum at about 5 per cent. of cobalt, and afterwards increases, as the content of cobalt is increased. The measurement of the thermal expansion of alloys having small expansibility was made from the temperature of liquid air to the vicinity of the critical point, and the range of temperature available for this small expansibility was examined. The smallest coefficient of expansion found in the present investigation in the vicinity of room temperature was less than 10^{-7}.—Science Reports of the Tôhoku Imperial University.

OVER
2000 PAIRS OF
Sterling
ROLLED STEEL
MOULDING BOXES
ARE IN DAILY USE IN
MESSRS WALLWORK'S
FOUNDRY.
A view of which
you see here.

Wallwork

For quantity production of accurate castings the name of Henry Wallwork & Co., of Manchester, stands pre-eminent. Sterling Boxes help them to maintain their reputation and supremacy.

STERLING BOXES ARE A PROFIT PAYING PROPOSITION

STERLING FOUNDRY SPECIALTIES Limited
LONDON OFFICE—13 VICTORIA STREET, S.W.1
AGENTS AT MANCHESTER,
GLASGOW & NEWCASTLE-ON-TYNE.
BEDFORD

WEEKLY PRICE CURRENT.

COPPER.

	£	s.	d.
Standard cash	35	3	9
Three months	35	17	6
Electrolytic	38	0	0
Tough	35	15	0
Best selected	36	5	0
Sheets	70	0	0
India	49	10	0
Wire bars	39	7	6
Do., July	39	7	6
Do., August	39	7	6
Ingot bars	39	7	6
H.C. wire rods	41	0	0
Off. av. cash, May	38	18	10½
Do., 3 mths., May	39	11	10⅞
Do., Sttlmnt., May	38	18	10½
Do., Electro, May	42	13	1½
Do., B.S., May	40	16	4⅝
Do., wire bars, May	43	2	9
Solid drawn tubes			10½d.
Brazed tubes			10½d.
Wire			6¾d.

BRASS.

Solid drawn tubes	9½d.
Brazed tubes	11½d.
Rods, drawn	8¾d.
Rods, extd. or rlld.	5d.
Sheets to 10 w.g.	7¼d.
Wire	7¾d.
Rolled metal	7½d.
Yellow metal rods	5d.
Do. 4 × 4 Squares	5½d.
Do. 4 × 3 Sheets	5½d.

TIN.

	£	s.	d.
Standard cash	103	2	6
Three months	104	12	6
English	106	5	0
Bars	106	0	0
Straits	105	0	0
Australian	104	0	0
Eastern	105	10	0
Banca	106	0	0
Off. av. cash, May	104	8	0
Do., 3 mths., May	105	14	10½
Do., Sttlmt., May	104	8	0

SPELTER.

	£	s.	d.
Ordinary	10	17	6
Remelted	9	10	0
Hard	7	5	0
Electro 99.9	12	10	0
English	10	15	0
India	10	0	0
Zinc dust	19	0	0
Zinc ashes	2	0	0
Off. aver., May	10	13	7½
Aver. spot, May	10	9	8¼

LEAD.

	£	s.	d.
Soft foreign ppt.	11	6	3
English	12	15	0
Off. average, May	11	12	8¼
Average spot, May	11	9	9¾

ZINC SHEETS, &c.

	£	s.	d.
Zinc sheets, English	20	0	0
Do., V.M. ex-whf.	19	0	0
Rods	20	10	0
Boiler plates	13	0	0
Battery plates	14	10	0

ANTIMONY.

	£	s.	d.
Special brand, Eng.	35	0	0
Chinese	22	10	0
Crude	19	0	0

QUICKSILVER.

	£	s.	d.
Quicksilver	16	15	0

FERRO-ALLOYS AND STEEL-MAKING METALS.

Ferro-silicon—	
25%	£7 10 0
45/50%	£10 10 0
75%	£15 0 0
Ferro-vanadium—	
35/50%	12/8 lb. Va.
Ferro-molybdenum—	
70/75% c. free	4/2 lb. Mo.
Ferro-titanium—	
23/25% carbon-free	9½d. lb.
Ferro-phosphorus, 20/25%	£15 10 0
Ferro-tungsten—	
80/85%	1/8½ lb.
Tungsten metal powder—	
98/99%	1/11½ lb.
Ferro-chrome—	
2/4% car.	£29 0 0
4/6% car.	£21 5 0
6/8% car.	£20 12 6
8/10% car.	£20 0 0
Ferro-chrome—	
Max. 2% car.	£29 17 6
Max. 1% car.	£34 2 6
Max. 0·70% car.	£36 0 0
70% carbon-free	9¾d. lb.
Nickel—99% £170 0 0 to £175 0 0	
Ferro-cobalt	9/- lb.
Aluminium 98/99%	£85 0 0
Metallic chromium—	
96/98%	2/7 lb.
Ferro-manganese (net)—	
76/80% loose £10 15 0 to £11 5 0	
76/80% packed £11 15 0 to £12 5 0	
76/80% export (nom.) £ 9 0 0	
Metallic manganese—	
94/96% carbonless	1/3 lb.

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

Finished bars, 14% tungsten	£0 2 0
Finished bars, 18% tungsten	£0 2 9

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to $\frac{3}{16}$ in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅜ in.	3d. lb.
Do., under ½ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP.

	£	s.	d.		£	s.	d.
South Wales							
Heavy steel	2	2	6	to	2	5	0
Bundled steel and shrngs.	1	15	0	to	2	0	0
Mixed iron and steel	1	17	6	to	1	18	6
Heavy cast iron	2	5	0	to	2	6	0
Good machinery for foundries	2	8	0	to	2	10	0
Cleveland—							
Heavy steel					2	0	0
Steel turnings					1	7	0
Cast-iron borings					1	4	0
Heavy forge					2	13	0
W.I. piling scrap					2	10	0
Cast-iron scrap	2	4	0	to	2	5	6
Midlands—							
Light cast-iron scrap					1	17	6
Heavy wrought					2	10	0
Steel turnings						—	
Scotland—							
Heavy steel	1	17	6	to	2	0	0
Ordinary cast iron					2	5	0
Engineers' turnings					1	6	0
Cast-iron borings					1	10	0
Wrought-iron piling					2	10	0
Heavy machinery					2	9	0

London—Merchants' buying prices delivered yard.

	£	s.	d.
Copper (clean)	26	0	0
Brass	18	0	0
Lead (less usual draft)	8	5	0
Tea lead	5	5	0
Zinc	3	15	0
New aluminium cuttings	46	0	0
Braziery copper	23	0	0
Gunmetal	25	0	0
Hollow pewter	68	0	0
Shaped black pewter	43	0	0

PIG-IRON.

(f.o.t. unless otherwise stated.)

N.E. Coast—	
Foundry No. 1	61/-
Foundry No. 3	58/6
Foundry No. 4	57/6
Forge No. 4	57/-
Hematite No. 1	64/6
Hematite M/Nos.	64/-
N.W. Coast—	
Hem. M/Nos. d/d Glas.	73/6
,, d/d Birm.	84/6
Malleable iron d/d Birm.	115/-
Midlands—	
Staffs common*	—
,, No. 4 forge*	61/-
,, No. 3 fdry.*	66/-
Shrops basic	—
,, Cold blast, ord.	—
,, ,, roll iron	—
Northants forge*	57/6
,, fdry. No. 3*	62/6
,, fdry. No. 1*	65/6
Derbyshire forge*	61/-
,, fdry. No. 3*	66/-
,, fdry. No. 1*	69/-
,, basic*	—

*d/d Black Country dist.

Scotland—	
Foundry No. 1	73/6
,, No. 3	71/-
Hem. M/Nos. d/d	70/-
Sheffield (d/d district)—	
Derby forge	58/6
,, fdry. No. 3	63/6
Lincs forge	—
,, fdry. No. 3	63/6
E.C. hematite	80/-
W.C. hematite	82/6
Lancashire (d/d eq. Man.)—	
Derby forge	62/-
,, fdry. No. 3	67/-
Staffs fdry. No. 3	67/-
Northants fdry. No. 3	65/6
Cleveland fdry. No. 3	67/-
Dalzell, No. 3 (special)	105/- to 107/6
Summerlee, No. 3	88/-
Eglinton, No. 3	88/-
Gartsherrie, No. 3	88/-
Monkland, No. 3	88/-
Shotts, No. 3	88/-

FINISHED IRON AND STEEL.

Usual District deliveries for iron; delivered consumers' station for steel.

	£	s.	d.		£	s.	d.
Iron—							
Bars (cr.)	9	15	0	to	10	10	0
Nut and bolt iron					8	12	6
Hoops	10	10	0	to	12	0	0
Marked bars (Staffs) f.o.t.					12	0	0
Gas strip	10	10	0	to	12	0	0
Bolts and nuts, ¾ in. × 4 in.					14	5	0
Steel—							
Plates, ship, etc.	8	15	0	to	8	17	6
Boiler plts.	8	17	6	to	9	12	6
Chequer plts.					10	7	6
Angles					8	7	6
Tees					9	7	6
Joists					8	15	0
Rounds and squares, 3 in. to 5½ in.					9	7	6
Rounds under 3 in. to ⅜ in. (Untested)	7	2	6	to	7	10	0
Flats—8 in. wide and over					8	12	6
,, under 8 in. and over 5 in.					8	17	6
Rails, heavy	8	5	0	to	8	10	0
Fishplates					12	0	0
Hoops (Staffs)					9	5	0
Black sheets, 24g.	8	5	0	to	9	5	0
Galv. cor. shts. 24g.	10	0	0	to	10	5	0
Galv. flat sheets	10	10	0	to	10	15	0
Galv. fencing wire, 8g. plain					12	0	0
Billets, soft	5	0	0	to	5	7	6
Billets, hard	6	12	6	&	up.		
Sheet bars	4	15	0	to	5	2	6
Tin bars					4	12	6

PHOSPHOR BRONZE.

	Per lb. basis.
Strip	11½d.
Sheet to 10 w.g.	11⅝d.
Wire	1/-
Rods	11⅝d.
Tubes	1/6½
Castings	11¾d.

Delivery 3 cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. Clifford & Son, Limited.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1½ to 1/7½
To 15 in. wide	1/1½ to 1/7½
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2½ to 1/8½
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3½
Ingots rolled to spoon size	10d. to 1/6½
Wire round—	
3/- to 10 g.	1/4½ to 1/11½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

AMERICAN IRON AND STEEL.

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	17.26
No. 2 foundry, Valley	17.00
No. 2 foundry, Birm.	12.00
Basic	17.26
Bessemer	18.76
Malleable	18.76
Grey forge	18.26
Ferro-mang. 80%	85.00
O.-h. rails, h'y, at mill	43.00
Billets	29.00
Sheet bars	29.00
Wire rods	35.00
	Cents.
Iron bars, Phila.	2.09
Steel bars	1.65
Tank plates	1.65
Beams, etc,	1.65
Skelp, grooved steel	1.65
Skelp, sheared steel	1.65
Steel hoops	1.85
Sheets, black, No. 24	2.15
Sheets, galv., No. 24	2.80
Sheets, blue an'l'd, No. 13	2.00
Wire nails	1.80
Plain wire	2.20
Barbed wire, galv.	2.55
Tinplates, 100-lb. box	$5.00

COKE (at ovens).

Welsh foundry	22/6 to 25/-
,, furnace	15/- to 16-
Durham and Northumberland—	
,, foundry	13/-
,, furnace	13/-
Midlands, foundry	—
,, furnace	—

TINPLATES.

f.o.b. Bristol Channel ports.

I.C. cokes	20×14 box	14/- to 14/3
,,	28×20 ,,	28/- to 28/6
,,	20×10 ,,	21/4½ to 21/7½
,,	18½×14 ,,	15/2 to 15/4½
C.W.	20×14 ,,	14/3
,,	28×20 ,,	28/3
,,	20×10 ,,	21/-
,,	18⅝×14 ,,	14/9
Terneplates	28×20	31/- per box basis f.o.b.

SWEDISH CHARCOAL IRON & STEEL.

Pig-iron	£6 0 0 to £7 10 0
Bars, hammered, basis	£17 10 0 to £18 10 0
Bars and nail-rods, rolled, basis	£15 17 6 to £16 15 0
Blooms	£10 0 0 to £12 0 0
Keg steel	£32 0 0 to £33 0 0
Faggot steel	£20 0 0 to £24 0 0
Bars and rods dead soft, st'l	£11 0 0 to £14 0 0

All per English ton, f.o.b. Gothenburg.

TUBES AND FITTINGS.

Current Discounts.

	Tubes.	*Fittings.*
Gas	62½%	57½%
Water ..	58½%	52½%
Steam ..	55%	47½%

W.I. 12½% extra.

DAILY FLUCTUATIONS.

Standard Copper (cash).

			£	s.	d.		
June	4	..	34	0	0	dec.	7/6
,,	5	..	35	7	6	inc.	27/6
,,	8	..	34	10	0	dec.	17/6
,,	9	..	35	3	9	inc.	13/9
,,	10	..	35	3	9	No	change

Electrolytic Copper.

			£	s.	d.		
June	4	..	38	0	0	dec.	20/-
,,	5	..	38	0	0	No	change
,,	8	..	38	0	0	,,	,,
,,	9	..	38	0	0	,,	,,
,,	10	..	38	0	0	,,	,,

Standard Tin (cash).

			£	s.	d.		
June	4	..	100	5	0	dec.	2/6
,,	5	..	100	10	0	inc.	5/-
,,	8	..	100	12	6	,,	2/6
,,	9	..	100	15	0	,,	2/6
,,	10	..	103	2	6	,,	47/6

Tin (English ingots).

			£	s.	d.		
June	4	..	101	5	0	dec.	5/-
,,	5	..	101	10	0	inc.	5/-
,,	8	..	101	15	0	,,	5/-
,,	9	..	101	15	0	No	change
,,	10	..	104	5	0	inc.	50/-

Zinc Sheets (English).

			£	s.	d.		
June	4	..	20	0	0	No	change
,,	5	..	20	0	0	,,	,,
,,	8	..	20	0	0	,,	,,
,,	9	..	20	0	0	,,	,,
,,	10	..	20	0	0	,,	,,

Spelter (ordinary).

			£	s.	d.		
June	4	..	9	13	9	No	change
,,	5	..	9	18	9	inc.	5/-
,,	8	..	10	0	0	,,	1/3
,,	9	..	10	5	0	,,	5/-
,,	10	..	10	17	6	,,	12/6

Lead (English).

			£	s.	d.		
June	4	..	12	0	0	No	change
,,	5	..	12	5	0	inc.	5/-
,,	8	..	12	0	0	dec.	5/-
,,	9	..	12	5	0	inc.	5/-
,,	10	..	12	15	0	,,	10/-

AVERAGE PRICES OF GALVANISED CORRUGATED SHEETS (NORTH OF ENGLAND).

Year.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1901	13 0 0	12 5 0	11 10 0	11 16 0	11 10 0	11 10 0	11 10 0	11 10 0	12 0 0	12 0 0	12 0 0	12 0 0	11 17 1
1902	12 0 0	11 10 0	11 10 0	11 10 0	11 15 0	11 15 0	11 15 0	11 15 0	11 15 0	11 15 0	11 15 0	11 15 0	11 14 2
1903	11 5 0	11 5 0	11 5 0	11 10 0	11 10 0	11 10 0	11 10 0	11 10 0	11 5 0	11 5 0	11 5 0	11 5 0	11 7 1
1904	11 5 0	11 5 0	11 5 0	11 5 0	10 15 0	10 15 0	10 15 0	10 15 0	10 5 0	10 5 0	10 5 0	10 5 0	10 15 0
1905	10 7 6	10 7 6	10 7 6	10 7 6	10 7 6	10 7 6	10 7 6	10 7 6	11 0 0	11 5 0	11 15 0	12 0 0	10 15 0
1906	12 12 6	12 12 6	12 12 6	12 7 6	12 7 6	12 7 6	12 12 6	12 12 6	12 15 0	12 15 0	12 15 0	13 5 0	12 13 11½
1907	13 5 0	13 5 0	13 15 0	13 15 0	13 15 0	13 15 0	13 17 6	13 17 6	13 17 6	13 2 6	13 2 6	13 2 6	13 10 10
1908	13 2 6	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 11 0½
1909	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	10 10 0	11 0 0	11 0 0	11 0 0	11 0 0	11 16 8
1910	11 15 0	12 5 0	12 5 0	11 15 0	11 10 0	11 10 0	11 12 6	11 12 6	11 12 6	11 12 6	11 10 0	11 10 0	11 18 4
1911	11 5 0	11 1 3	10 15 0	10 15 0	10 13 9	10 10 0	10 13 9	11 0 0	11 5 0	11 5 0	11 5 0	11 7 0	10 19 7½
1912	11 10 0	11 10 0	11 10 0	11 15 0	12 5 0	12 5 0	12 5 0	12 5 0	12 5 0	12 12 6	12 18 0	12 15 0	12 2 11½
1913	12 15 0	12 15 0	12 15 0	12 11 3	11 18 0	11 15 0	11 15 0	11 15 0	11 15 0	11 3 0	11 0 0	11 2 6	11 18 4
1914	11 7 0	11 7 6	11 7 6	11 5 7½	11 2 6	10 15 0	10 15 0	12 17 6	14 2 0	13 7 0	11 15 7	11 2 6	11 16 0
1915	11 10 8½	13 12 6	14 8 9	15 0 6	17 17 6	20 17 6	20 17 6	20 6 3	17 12 6	18 1 0	22 13 9	25 2 0	18 3 4½
1916	26 5 0	27 12 6	28 0 0	28 5 0	29 0 0	29 0 0	28 15 0	28 3 0	28 15 0	28 15 0	28 15 0	28 15 0	28 6 8½
1917	28 15 0	28 15 0	28 15 0	28 15 0	28 15 0	28 15 0	28 15 0	28 15 0	28 15 0	28 0 0	28 0 0	28 0 0	28 11 3
1918	28 5 0	28 15 0	29 0 0	29 0 0	29 0 0	29 0 0	29 0 0	29 0 0	29 0 0	29 0 0	29 0 0	29 0 0	28 13 4
1919	29 0 0	29 0 0	29 0 0	28 0 0	28 10 0	27 7 6	27 5 0	29 3 0	32 0 0	33 0 0	36 10 0	40 8 4	31 5 3½
1920	46 10 0	49 15 0	53 15 0	56 0 0	55 10 0	54 10 0	52 10 0	48 10 0	44 3 4	39 2 6	35 17 6	30 8 0	47 4 8
1921	28 10 0	25 17 6	24 5 0	23 3 4	22 0 0	22 0 0	23 10 0	21 12 6	20 0 0	18 15 0	18 3 9	17 2 0	22 1 7
1922	16 17 6	15 13 9	16 3 0	16 10 0	16 4 4½	15 15 6	15 16 3	16 16 0	16 8 9	16 6 3	17 1 0	17 7 6	16 7 5½
1923	18 3 1½	19 1 11½	19 8 0	19 10 0	19 7 0	19 1 3	18 0 0	18 13 1½	19 0 0	19 3 9	19 2 6	18 19 4½	18 19 2
1924	18 13 6	18 9 4½	18 5 0	17 15 11½	17 3 0	17 19 4½	18 7 6	18 8 1½	18 8 1½	17 19 6	17 11 3	17 10 0	18 0 10½
1925	17 8 6	17 1 6½	16 9 4½	16 12 0	16 9 8½	16 9 4½	16 0 6	16 1 10½	16 5 0	16 7 0	16 12 6	6 15 0	16 11 0½
1926	16 14 4½	16 5 7½	16 0 6	15 11 10½	15 11 3	16 0 0	16 16 0	16 18 9	16 14 0	16 18 9	17 10 0	6 19 0	16 10 0½
1927	16 3 1	15 7 6	15 3 3	15 3 1½	14 14 4½	14 11 6	14 1 10½	14 0 0	13 19 6	13 16 10½	13 13 1½	13 3 9	14 9 10
1928	13 0 0½	13 2 6	13 6 0	13 2 6	13 3 0	13 6 9	13 11 3	13 10 0	13 10 7½	13 12 6	13 11 6	13 10 0	13 8 8½
1929	13 11 0	13 13 1½	13 12 9½	13 10 11½	13 9 3	13 8 9	13 11 6	13 7 6	13 7 6	13 5 6	12 18 9	12 12 9½	13 7 5½
1930	12 5 0	11 15 0	11 19 6	11 18 7	11 18 0	11 17 6	11 17 6	11 17 6	11 16 3	11 12 6	11 8 9	11 5 0	11 15 11½
1931	11 4 0	11 0 0	11 0 0	11 0 0	10 13 9	—	—	—	—	—	—	—	—

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